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III. SUNFLOWER FAMILY

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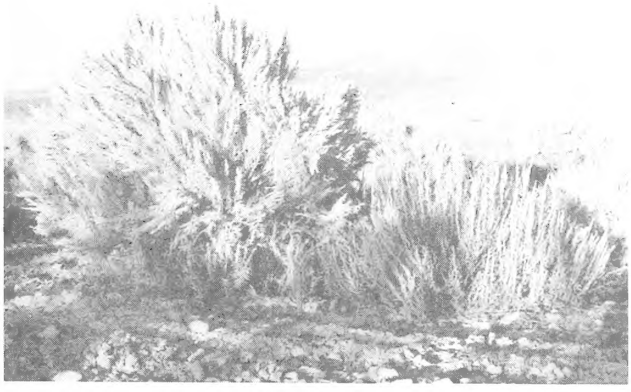

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CHARACTERISTICS AND HYBRIDIZATION OF IMPORTANT INTERMOUNTAIN SHRUBS III. SUNFLOWER FAMILY

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RESEARCH SUMMARY

Shrubs of the sunflower family are among the most common and important plants of the Intermountain area. In many valley, foothill, and mountain locations, composite shrubs, especially the sagebrushes and rabbitbrushes, provide the principal vegetation. These shrubs are invaluable as ground cover on natural and disturbed landscapes, as forage for wild and domestic herbivores, and as habitat for smaller creatures. The authors discuss and review vegetative, floral, and reproductive characteristics, hybridization, distribution and habitat, use, and division into subspecies entries for important Intermountain species. The following genera are covered: Artemisia, Chrysothamnus, Tetradymia, and Xanthocephalum (Artemisia arbuscula, A. bigelovii, A. cana, A. filifolia, A. frigida, A. longiloba, A. nova, A. pygmaea, A. rigida, A. rothrockii, A. spinescens, A. tridentata, A. tripartita, Chrysothamnus albidus, C. depressus, C. greeni, C. linifolius, C. nauseosus, C. parryi, C. vaseyi, C. viscidiflorus, Tetradymia canescens, T. glabrata, T. nuttallii, T. spinosa, Xanthocephalum microcephala, and X. sarothrae). Hybridization experiments and the possibility of plant improvement are discussed for section Tridentatae of Artemisia. A key to the taxa discussed is provided.

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The Snow Field Station, Ephraim, Utah, at which experiments were performed and observations made, is cooperatively maintained by the Intermountain Forest and Range Experiment Station, Utah State Division of Wildlife Resources, Utah State University, and Snow College.

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INTRODUCTION

The sunflower family is the largest family of flowering plants. Its many species occur around the world (Benson 1957; Cronquist 1968). The family is well defined but diverse. Wagentiz (1976) stated, "The range of variability" of the sunflower family "in life form and other vegetative characters is . . . impressive if we remember the (family's) numerous annual herbs, herbaceous perennials, shrubs, and trees." It contains many beautiful, popular garden flowers, a large number of weeds, numerous useful wildland forbs, and some woody genera, including important browse species.

Four genera of this family, sagebrush (*Artemisia*), rabbitbrush (*Chrysothamnus*), horsebrush (*Tetradymia*) and matchweed (*Xanthocephalum*), are among the most common and important shrubs on western ranges. Approximately 11 percent (2,514,000 hectares or 9,700 square miles) of Utah is dominated by various species of sagebrush. These species produce the highest volume of forage of the various shrublands within the State (West 1974). Approximately 109,400,000 hectares (422,000 square miles) in the Western States have sagebrush in varying amounts growing on them (Beetle 1960). Horsebrush, matchweed, and rabbitbrush, particularly rubber rabbitbrush (*C. nauseosus*) and low rabbitbrush (*C. viscidiflorus*), are commonly associated with sagebrush throughout the western United States.

Shrubs of these genera provide critically needed ground cover on arid western ranges, are important sources of browse for domestic livestock and big game, and serve as cover and forage for wildlife. Various forms of sagebrush and rabbitbrush may also be used for landscaping and for stabilizing and beautifying disturbed landscapes. Young wildings of both sagebrush and rabbitbrush transplant easily. Usually within 3 to 7 years they are established sufficiently to reproduce naturally from seed. Both establish well when aerially seeded (Plummer and others 1968; McArthur and others 1974; Plummer 1977).

The purpose of this paper is to document what is known about shrubs of the sunflower family in the Intermountain area, particularly their vegetative and flowering characteristics, hybridization, distribution, and use. Most of the observational information and experimental data were gathered from the Intermountain area, especially from Utah. The Intermountain area includes all of Utah, that portion of Arizona north of the Grand Canyon, most of Nevada, parts of California that lie within the Great Basin, the sagebrush areas of southeastern Oregon, southern Idaho to the high mountainous areas to the north, and the Red Desert area of southwestern Wyoming (Holmgren and Reveal 1966). However, reference to and comments on species distribution and characteristics outside this area are made as appropriate.

Each species, its hybridization, distribution and habitat, and use are described in detail. Each genus and its species and subspecies included in this publication are arranged in alphabetical order. A taxonomic key (appendix) is given for the included genera, species, and subspecies. This paper is the third in a series on Intermountain shrub species; the first was on the Rose family and the second was on the Chenopod family (Blauer and others 1975, 1976).

METHODS

Many accessions of Compositae genera have been transplanted into the uniform garden at the Snow Field Station in Ephraim, Utah (fig. 1), and at various other study and research areas. Observations and data collection on these plants and on plants occurring in many natural populations throughout the Intermountain area have provided the basis for this report. Much of the data collection has been for preparation of published and yet to be published reports (Plummer and others 1968; Hanks and others 1973, 1975; Plummer 1977; McArthur and Pope 1977; McArthur and Plummer 1978; McArthur and others 1978; McArthur 1979). Observations and collections were made so the floral and vegetative characteristics of the shrubs as well as their use, distribution, and habitat could be described and illustrated. Herbarium voucher specimens representing many of these populations have been deposited in the Shrub Sciences Laboratory Herbarium (SSLP). Photographic illustrations are from plants in natural settings and at experimental planting sites. Drawings of herbarium specimens are of plants from natural populations or from plants transplanted from natural populations onto the Snow Field Station. The latter are identified by culture numbers of the "U" series.

Literature pertaining to the Compositae genera we treat was surveyed and is cited throughout the paper. Existing keys and monographs were consulted in the preparation of our key.

In cases where the seeds per gram information was unknown, seeds were collected from 3 to 10 accessions. A minimum of 3 cleaned lots of 100 seeds each were counted and weighed on an analytical balance for each accession. The seeds-per-gram information was then extrapolated.

Hybridization experiments were first conducted in 1972 using hot water and chemical treatments in an attempt to induce male sterility in *Artemisia* and *Chrysothamnus*. Treatments were at different stages of phenological development, from early bud to just prior to anthesis. Hot water treatments following Hayes and others (1955) were from 40° C to 50° C for 2 to 10 minutes. The chemical treatment used was spraying Amchem's Ethrel (2-Chloroethylphosphonic acid) at concentrations of 100 to 12,000 parts per million on the inflorescences following Rowell and Miller (1971).

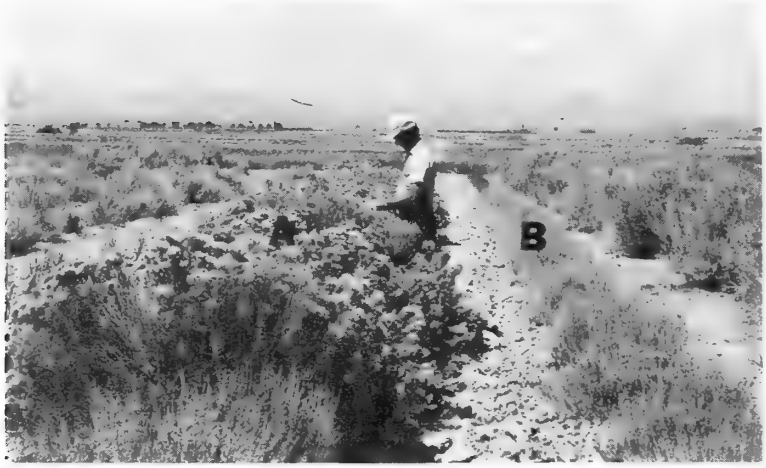

Figure 1.--Mature plants of composite accessions transplanted as wildings at Snow Field Station. (A) Chrysothamnus nauseosus *ssp.* salicifolius *(mountain rubber rabbitbrush). (B)* Artemisia rothrockii *(timberline sagebrush).*

Because neither the hot water nor the chemical treatments proved effective, subsequent efforts on section *Tridentatae* of *Artemisia* were in the form of mass pollination in white bakery bags or white, woven Terylene fabric bags (fig. 2). (Other types of pollination bags trapped excessive heat and humidity that caused excessive damage or death of enclosed plant tissue.) Four treatments were made: (1) a control where the bags were placed over some inflorescences and not opened again until the pollination season was over; (2) an intrapopulation treatment where an inflorescence containing pollen was inserted into the bag from another plant from the same accession; (3) an interpopulation treatment where pollen from another taxon was inserted into the bag--two of these were made on each plant; and (4) an open pollination where no bag was placed on the inflorescence but it was marked with a string so an equivalent seed source could be collected.

After pollen was inserted, all bags were shaken to facilitate pollination. This practice was continued every 2 or 3 days for about 10 days. About 3 or 4 weeks after pollinations, the bags were opened. The plants were monitored until seeds were ripe and about to shatter, at which time the seeds were collected. Seeds were cleaned in a forced-air seed separator. They were then counted in petri dishes with centimeter squares marked on the bottom. Exact counts were made when no more than 100 seeds were produced. Higher numbers (up to 5,000) were estimated by randomly distributing the seed in the petri dishes, counting a known area of the dish, and extrapolating. To test differences in pollination treatments, an analysis of variance followed by a multiple-range test was employed (Woolf 1968).

CHARACTERISTICS OF THE GENUS *ARTEMISIA* (SAGEBRUSH)

Artemisia is a large genus of approximately 200 species that occurs primarily in dry areas in the temperate regions of North America, North Africa, and Eurasia. *Artemisia* is most common in arid, steppe areas. Its extension south of the temperate zone usually is confined to mountainous habitats. Many of the species, especially in the western United States, are called sage or sagebrush. Old World names such as wormwood or mugwort have also been applied in the United States (Grieve 1931; Sampson and Jesperson 1963; Bailey Hortorium Staff 1976).

Figure 2.--Hybridization experiments with big sagebrush at the Snow Field Station. The pollination bags are of woven Terylene fabric with observation windows of clear plastic.

The genus consists of annual, biennial, and perennial herbs; subshrubs and shrubs of various sizes ranging from less than 2 dm up to 4.5 m. These plants contain volatile oils. All are aromatic, some strongly so; most emit a pronounced characteristic "sage" smell when the herbage is crushed. The glabrous to tomentose leaves are borne alternately. Leaves are entire to variously lobed or dissected.

Sagebrush flowers are very small and are borne in numerous small heads commonly arranged into panicles or sometimes racemes or spikelike inflorescences but never into cymes (see figure 5, page 7). Each head has a cuplike involucre made up of 2 to 4 series of dry, papery, closely overlapping bracts. Depending on the species, the heads contain either both ray and disc flowers or only disc flowers (fig. 3). The ray flowers, when present, are pistillate and fertile and have 2-cleft, more or less exserted styles. The disc flowers are perfect and fertile or sometimes sterile and each has a tubular to trumpet-shaped corolla with 5 stamens united by their anthers around the normally 2-cleft style. The ovary develops into a glabrous or resinous-granuliferous achene. Pappus is lacking in the vast majority of the species. Although basic chromosome numbers of x = 6, 7, 8, and 9 are known, x = 9 is the most common base number (Ward 1953; Kawatani and Ohno 1964; Wiens and Richter 1966). Polyploidy is common in the genus.

Natural hybridization among various taxa of western sagebrush seems to be widespread and common (Beetle 1960; Hanks and others 1973). Beetle (1960) believes several species and subspecies have originated through hybridization and subsequent polyploidy.

A number of *Artemisia* species and their subspecies are valuable browse plants, especially on winter and early spring ranges. These include *A. tridentata, A. nova, A. arbuscula, A. cana, A. spinescens, A. frigida, A. filifolia, A. longiloba, A. bigelovii,* and *A. rothrockii.* These and others are also useful for controlling soil erosion. *Artemisia* species are also browse plants of considerable importance in steppes of Eurasia and North Africa (Polyakov 1961). Larin (1956) stated "representatives of *Artemisia* have the greatest fodder importance of all the Compositae . . . . They clearly dominate the desert (of the U.S.S.R.) both in their quantity in the vegetative cover and in their fodder importance." *Artemisia* is essential in the maintenance of sage grouse populations (Braun and others 1977) as well as populations of other birds and small animals. Members of the herbaceous *Artemisia ludoviciana* complex are particularly good for soil stabilization (Monsen 1975).

Some species (*A. mexicana, A. absinthium, A. cina*) have long been used medicinally, mainly as a remedy for roundworms and are thus commonly known as wormwood. Other

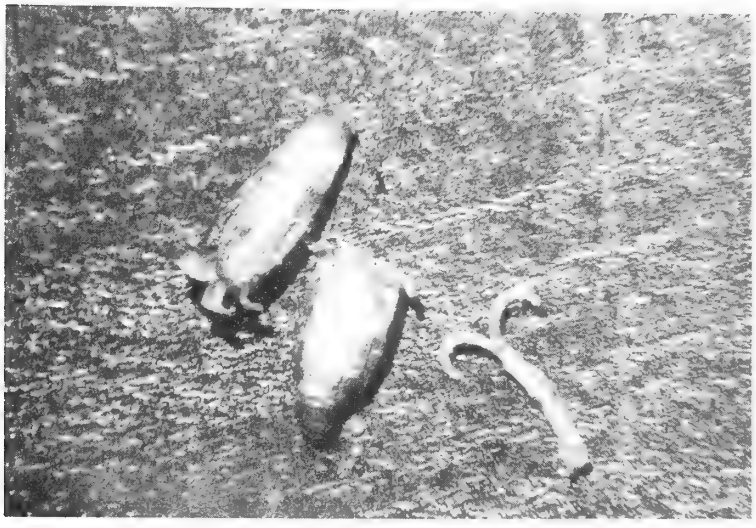

Figure 3.--A ray flower and two disc flowers (left) from an Artemisia bigelovii *flower head (12X).*

species are used for flavoring. Hopi Indians flavor sweet corn by roasting leaves of *A. frigida* along with the corn (Kearney and Peebles 1960). In Europe, *A. absinthium* and *A. barrelieri* are used in preparation of the alcoholic beverages, absinthe and Algerian absinthe, respectively. Vermouth derives from a German appelation for wormwood. Tarragon (*A. dracunculus*) is used to flavor vinegar and as seasoning. Silvery foliage, interesting leaf patterns, and pleasant odor make several species popular as ornamentals. One of the most attractive ornamental shrubs is the California native, *A. pycnocephala*. An Old World introduction, *A. stelleriana*, is the "Dusty Miller" of our gardens. Oldman wormwood (*A. abrotanum*) has had long usage as an ornamental hedge shrub (Sampson and Jesperson 1963). More recently, *A. caucasica* has been introduced to this country and is finding use as an attractive prostrate border plant.

Classically, *Artemisia* has been taxonomically divided into four sections or subgenera (*Abrotanum*, *Absinthium*, *Dracunculus*, and *Seriphidium*). These sections are recognized primarily on the basis of flower characteristics--absence or presence and fertility or infertility of disc and ray flowers (see McArthur and Plummer 1978; and McArthur 1979 for review). We prefer to recognize the four sections: *Artemisia*, *Dracunculus*, *Seriphidium*, and *Tridentatae* (table 1). In this scheme, *Abrotanum* and *Absinthium* are combined to form *Artemisia* (Polyakov 1961). This union seems natural because the original separation was based only on the difference in hairiness of the floral receptacle. *Tridentatae* was recognized as being separate from *Seriphidium* on the basis of disjunct present and past distribution patterns, different basic karyotypes, and chemotaxonomic differences (McArthur and Plummer 1978).

Table 1.--Taxonomic sections of *Artemisia*

Classical sections[1]	Modern sections[2]	Distinguishing characteristics	Distribution	Species mentioned in this paper
Absinthium Abrotanum	Artemisia	Pistillate ray flowers, perfect disc flowers; predominantly herbaceous but a few are woody.	Eurasia, North Africa, North America.	*A. abrotanum* *A. absinthium* *A. californica* *A. caucasica* *A. frigida* *A. ludoviciana* *A. mexicana* *A. stelleriana* *A. vulgaris*
Dracunculus	Dracunculus	Pistillate ray flowers, staminate disc flowers; herbaceous and woody.	Eurasia, North America.	*A. dracunculus* *A. filifolia* *A. pedatifida* *A. pycnocephala* *A. spinescens*
Seriphidium	Seriphidium	Ray flowers lacking, perfect disc flowers; herbaceous and woody.	Eurasia, North Africa[4]	*A. barrelieri* *A. cina* *A. herba-alba* *A. maritima*
	Tridentatae	Ray flowers lacking,[3] perfect disc flowers; woody.	North America	*A. arbuscula* *A. argilosa* *A. bigelovii* *A. cana* *A. longiloba* *A. nova* *A. pygmaea* *A. rigida* *A. rothrockii* *A. tridentata* *A. tripartita*

[1]DeCandolle 1837, Hooker 1840, McArthur and Plummer 1978, McArthur 1979.
[2]Rydberg 1916, Beetle 1960, Polyakova 1961, McArthur and Plummer 1978, McArthur 1979.
[3]The single exception, *A. bigelovii*, has 0-2 pistillate ray flowers on otherwise discoid heads.
[4]Two anomalous American species have been referred to Seriphidium: *A. palmeri* of southern and Baja California and *A. mendozana* from Argentina.

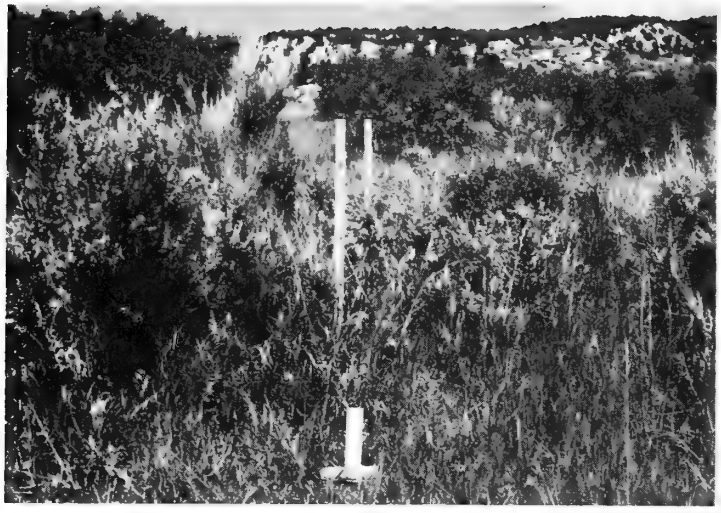

Figure 4.--Mountain big sagebrush (Artemisia tridenta a *ssp.* vaseyana) *growing in a luxuriant stand of smooth brome* (Bromus inermis) *in Ephraim canyon, Utah.*

Artemisias contain a variety of natural chemical products, most notably terpenoids and phenolics. Many individual compounds have been isolated and identified, particularly in recent years. Terpenoids include the monoterpenes of the essential oils that produce the characteristic odors of sagebrushes and wormwoods (Guenther 1952; Halligan 1975; Buttkus and others 1977; Scholl and others 1977). Sesquiterpene lactones are another class of terpenoids common in the *Artemisias* (Kelsey and others 1973; Geissman and Irwin 1974; Rodriguez and others 1976). Two principal classes of phenolic compounds are present, the coumarins (Shafizadeh and Melnikoff 1970; Brown and others 1975) and the flavonoids (Rodriguez and others 1972; Segal and others 1973; Brown and others 1975).

In addition to terpenoids and phenolics, a third class of chemicals--the alkane hydrocarbons--was studied by Bachelor and others (1972). The rich array of natural chemical products in *Artemisia* has proven to be useful in delimiting taxonomic boundaries (Hanks and others 1973; Kelsey and others 1973; and Geissman and Irwin 1974). Although the physiological importance of many of the natural chemical products is unknown, some have been implicated in the allelopathic properties of *Artemisia*. Many *Artemisias* have allelopathic qualities; under certain conditions they may chemically inhibit growth of seedlings and established plants of competitive species, and even growth of their own seedlings. These allelopathic qualities might contribute to the dominant position of sagebrushes and wormwoods in many communities. *A. californica, A. absinthium, A. herba-alba, A. vulgaris, A. tridentata,* and *A. cana* have been shown to have allelopathic properties (Schlatterer and Tisdale 1969; Halligan 1975; Friedman and others 1977; Hoffman and Hazelett 1977; Weaver and Klarich 1977). Nevertheless, in many instances *Artemisias* are part of communities rich in species (fig. 4). So, the significance of allelopathy in *Artemisia* communities remains in doubt.

The natural chemical products might account for the differential palatability among *Artemisia* taxa (Hanks and others 1973; Sheehy and Winward 1976; Scholl and others 1978).

Artemisia arbuscula Nutt. (low sagebrush[1])

Low sagebrush is a low, spreading, irregularly branched shrub up to 5 dm high (fig. 5a). The slender erect twigs are densely canescent, but may become nearly glabrous and thus darker green in late summer. The plant layers infrequently.

[1]Also called little sagebrush, scabland sagebrush, dark sagebrush.

Figure 5.--Artemisia *species. (A)* A. arbuscula, *Culture U6, Salina Canyon, Sevier Co., Utah (1.3X). (B)* A. bigelovii, *Culture U13, Chinle, Apache Co., Arizona (1.0X). (C)* A. nova, *Culture U7, Gunnison, Sanpete Co., Utah (1.1X). (D)* A. rothrockii, *Culture U2, Olsen's Bench, Wasatch Plateau, Sanpete Co., Utah (0.9X).*

Figure 6.--Low sagebrush (A. arbuscula) growing on the rocky flanks of Indian Peak, Beaver Co., Utah.

Leaves are broadly cuneate or fan-shaped, 0.5 to 1.5 cm long, 0.3 to 1 cm wide and are usually 3 (occasionally 4 to 5) toothed or cleft at the apex. Leaves on the upper part of the flowering shoots may become entire.

Flower heads are grouped into elongated, narrow racemose panicles (fig. 5a). The heads usually contain from 5 to 11 disc flowers with corollas 3 to 4 mm long. The 10 to 15 involucral bracts are canescent. Flowering occurs from August to September, depending upon strain and elevation. Seed ripens in October and November. Cleaned seed averages 2,160 per gram (980,000 per pound) (Deitschman 1974).

Hybridization.--This species has a basic chromosome number of $x = 9$. Both diploid ($2n = 18$) and tetraploid ($2n = 36$) forms are known (Ward 1953; McArthur and Plummer 1978). Intermediates between low sagebrush and both *A. tripartita* ssp. *tripartita*, and *A. tridentata* ssp. *tridentata* have been reported by Beetle (1960). Hanks and others (1973) found chromatographic evidence of hybridization between low sagebrush and *A. tridentata* ssp. *vaseyana*. Ward (1953) united both low sagebrush and black sagebrush (*A. nova*) into a single species partly because he felt they intergrade into one another.

However, Ward (1953) found that most specimens of black sagebrush he examined were tetraploid, whereas most specimens of low sagebrush were diploid. This difference in chromosome number could be a barrier to free interbreeding, because populations of the two species with the same number of chromosomes are not known to occur together. In fact, the two species rarely occur together (Ward 1953). On the basis of field collections, Beetle (1971) argued persuasively for separate species status for the two sagebrushes.

A dwarf form of *A. arbuscula* occurs in the Stanley Basin area of Idaho, the Jackson Hole, Wyoming area, and perhaps in other locations. Beetle (1959, 1960) named this form *A. arbuscula* ssp. *thermopola*--hotsprings sagebrush. Beetle speculated that this form arose as the result of hybridization between typical *A. arbuscula* and *A. tripartita*.

Distribution and habitat.--Low sagebrush grows on dry, sterile, rocky, often alkaline soils betweeen 700 and 3,500 meters (2,300 and 11,500 feet) approximately 10,135,000 hectares (39,112 square miles) in 11 western States (Beetle 1960; Ward 1953) (fig. 6). In the warmer, drier parts of its range, particularly in Nevada, it may grow well into the mountains above 3,000 meters (9,800 feet). In some areas, for example, east central Idaho, low sagebrush occurs on disjunct low and high elevation bands (E. F. Schlatterer, letter 12/1/77).

Figure 7.--Bigelow sagebrush (A. bigelovii) growing at the Snow Field Station. The ruler is 30 cm long.

Low sagebrush ranges from southern Colorado to western Montana and west throughout Utah and Idaho to northern California, Oregon, and Washington. Type locality is listed as "arid plains of Lewis (Snake) River" (Beetle 1960). Normally its sites are drier and more rocky than those on which big sagebrush occurs. Low sagebrush and black sagebrush rarely occur in intermixed stands, for example, the Lost River-Lemhi Range area of Idaho (E. F. Schlatterer, letter 12/1/77). In areas where the distribution of these two species overlaps, low sagebrush is usually found in the more moist habitats or at slightly higher elevations than black sagebrush (Ward 1953).

Use.--On winter ranges and to a limited extent on summer ranges, low sagebrush is browsed by big game and livestock. There is considerable variation in how animals browse it in different locations. In Nevada, the gray-green form may be heavily browsed while the green form is only lightly browsed (Brunner 1972). Sage grouse also apparently prefer the lighter form to the darker one. Similarly, black sagebrush also has two color morphs, with the light (gray-green) one preferred by browsing animals.

Artemisia bigelovii Gray. (Bigelow sagebrush)

Bigelow sagebrush is a low shrub 2 to 4 dm high with numerous spreading branches. The flowering stems are slender and erect and bear inflorescences that are long, narrow panicles with short, recurved branches (figs. 5b, 7). New growth is covered with a silvery-canescent pubescence.

The leaves of vegetative branches are similar to those of big sagebrush. They are narrowly cuneate, 1 to 2 cm long, 2 to 5 mm wide, and normally tridentate, but may show various abnormal tips. The odor of crushed leaves is mild like that of mountain big sagebrush (*A. tridentata* ssp. *vaseyana*).

The heads are arranged into elongated, narrow panicles and normally contain 1 but occasionally 0 to 2 ray flowers and 1 to 3, usually 2, disc flowers (fig. 3). The turbinate involucre consists of 8 to 12 short, densely tomentose bracts 2 to 4 mm long and 1.5 to 2.5 mm broad. Flowering occurs from August to October. Cleaned seed averages 5,975 per gram (2,710,000 per pound).

Bigelow sagebrush closely resembles and is often mistaken for low forms of big sagebrush produced by overgrazing and burning. In contrast to big sagebrush, however, it has ray flowers. Furthermore, lobes of *A. bigelovii*'s vegetative leaves are always more shallow and more sharply dentate than those of big sagebrush.

*Figure 8.--Bigelow sagebrush (*A. bigelovii*) growing with fourwing saltbush (*Atriplex canescens*) in a gravelly draw near Bicknell, Wayne Co., Utah.*

A. bigelovii is normally free of insect galls and rust diseases that are common in the other taxa of the section *Tridentatae* (Beetle 1960).

Hybridization.--This species has a basic chromosome number of $x = 9$. Both diploid ($2n = 18$) and tetraploid ($2n = 36$) forms are known (Ward 1953; McArthur and Plummer 1978).

Bigelow sagebrush and basin big sagebrush are often found growing together but are not known to cross or intergrade.

Distribution and habitat.--Bigelow sagebrush has a more southerly distribution than other sagebrushes. It is one of the most drought-resistant sagebrushes. It occurs over approximately 8,810,000 hectares (34,010 square miles) through western Texas, southern Colorado, New Mexico, Arizona, Utah, Nevada, and California in canyons, gravelly draws and dry flats from 900 to 2,400 meters (3,000 to 7,900 feet) (Ward 1953; Beetle 1960; Kearney and Peebles 1960) (fig. 8). The Bigelow sagebrush type locality is recorded as "rocks and canyons on the Upper Canadian, Texas" (Beetle 1960).

This species is often found mixed with big sagebrush, black sagebrush, leafless green rabbitbrush (*Chrysothamnus nauseosus* ssp. *junceus*), shadscale (*Atriplex confertifolia*), and especially matchbrush (*Xanthocephalum* [*Gutierrezia*] *sarothrae*) (Hall and Clements 1923).

Use.--Bigelow sagebrush is palatable to livestock and game in all areas where it occurs. Its twigs are less woody, its odor milder, and its taste is less bitter than most of the big sagebrush complex (Hall and Clements 1923).

Artemisia cana Pursh. (silver sagebrush[2])

Silver sagebrush is an erect, freely branched, rounded shrub up to 1.5 meters tall. Older branches have dark-brown, fibrous bark while younger branches are covered with a dense white to yellowish-green tomentum.

[2]Other common names are white sagebrush, hoary sagebrush, hoary silver sagebrush.

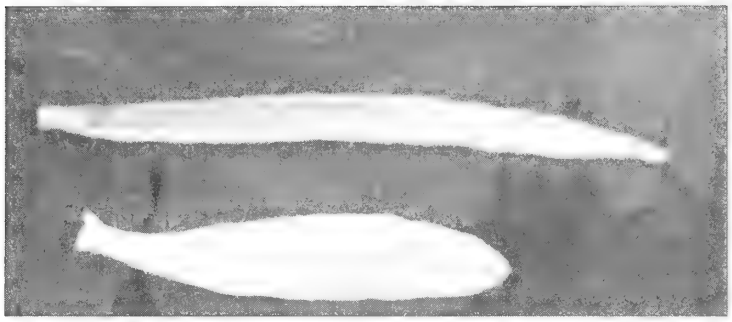

Figure 9.--Leaves of silver sagebrush. Top, A. cana *ssp.* viscidula; *bottom.* A. cana *ssp.* cana. *The longer leaf is 4 cm long.*

Leaves on the vegetative branches are 1 to 10 mm wide and 2 to 8 cm long, linear to linear-oblanceolate, entire or occasionally with 1 or 2 irregular teeth or lobes, silver-canescent becoming slightly viscid with age (figs. 9, 10). Leaves on the flowering stems are similar, but they may be slightly smaller, especially on the upper parts of the stems. The foliage emits a mild to pungent aromatic odor when crushed.

Numerous heads are arranged into dense, narrow, leafy panicles, sometimes reduced to raceme or spikelike inflorescence (fig. 10). Each head contains 4 to 20 disc flowers. Ray flowers are lacking. Achenes are granuliferous. Blooming occurs during August and September. Cleaned seed averages 4,900 per gram (2,220,000 per pound).

Hybridization.--Silver sagebrush occurs in both diploid ($2n = 18$) and tetraploid ($2n = 36$) forms (Ward 1953). Putative natural hybridization between subspecies of *A. cana* (*cana* and *viscidula*) and other shrubby species of *Artemisia* have been reported (Ward 1953; Beetle 1960; Hanks and others 1973).

Distribution.--Silver sagebrush occurs over approximately 13,790,000 hectares (53,221 square miles) from British Columbia to Saskatchewan, south to Nebraska, Colorado, and New Mexico, and west to Oregon and California on valleys, plains, foothills, and mountains up to 3,050 meters (10,000 feet) (Beetle 1960).

Use.--Silver sagebrush is important throughout its range as a browse shrub and is used quite extensively by livestock and big game, particularly when other food is scarce. In the western Great Plains area, silver sagebrush is an important antelope survival food. Like big sagebrush, this species has been used by white settlers and Indians for fuel. Silver sagebrush has been used as an ornamental in England (Hall and Clements 1923).

Figure 10.--Mountain silver sagebrush (A. cana *ssp.* viscidula) *on Targhee National Forest, Sublette Co., Wyoming, showing leaves and flower heads.*

Subspecies.--*Artemisia cana* ssp. *cana* (silver sagebrush) is an erect, rounded, freely branched shrub up to 1.5 meters tall. It layers whenever conditions are suitable. This subspecies may spread rapidly, particularly after burning, by rootsprouting and by rhizomes (Beetle 1960). Leaves of the vegetative branches are linear-oblanceolate, entire or rarely with 1 or 2 irregular teeth or lobes, 1 to 10 mm wide, 2 to 8 cm long, and are densely silky-canescent (fig. 9). Crushed foliage emits a pungent turpentine odor (Ward 1953; Beetle 1960). Flower heads are usually arranged into dense, leafy panicles and may contain from 5 to 20 disc flowers. Blooming occurs during September, and the seeds ripen during October and November. Putative natural hybrids between subspecies *cana* and both basin and mountain big sagebrush have been found (Ward 1953; Beetle 1960). Subspecies *cana* has a more eastern distribution than subspecies *viscidula*. It occurs from southern Canada southward, but mostly east of the Continental Divide, through Montana, the Dakotas, Wyoming, western Nebraska, and northern Colorado. Its type locality is "on the bluffs, Missouri River" (Beetle 1960).

Artemisia cana ssp. *viscidula* (mountain silver sagebrush) is an erect shrub that readily layers. It usually is not more than 1 meter tall. Leaves on the vegetative branches are 1 to 5 mm wide, up to 7 cm long (fig. 9), and are often crowded in dark-green clusters. The leaves typically are simple and entire but occasionally are variously toothed or lobed. This subspecies varies in appearance, but is always darker green than mountain big sagebrush with which it is often growing (Beetle 1960). Mountain silver sagebrush is distinguished from subspecies *cana* by its smaller, darker green leaves, its lower stature, and more western distribution. Flower heads are arranged into dense, short raceme or spikelike inflorescences 1 to 3 cm long. Each head contains from 4 to 15 disc flowers. Flowers bloom during August and September. Seed matures during October and November. Putative natural hybrids involving this subspecies and *A. tripartita* ssp. *tripartita*, *A. tridentata* ssp. *vaseyana*, and *A. tridentata* ssp. *tridentata* have been found (Beetle 1960; Hanks and others 1973). Beetle (1960) believes *Artemisia argilosa* may have arisen from a cross between *A. cana* ssp. *viscidula* and *A. longiloba*, and that *A. tridentata* ssp. *vaseyana* f. *spiciformis* may have developed from a cross between *A. cana* ssp. *viscidula* and *A. tridentata* ssp. *vaseyana*. Mountain silver sagebrush occurs in mountainous regions around 2,100 meters (6,900 feet) and above. It is usually found along streamsides and in areas of heavy, lingering snowpack from the southwest corner of Montana, south along the Continental Divide to New Mexico, and west to Arizona, Nevada, Utah, and Idaho. Mountain silver sagebrush type locality is Routt County, Colorado (Beetle 1960). A similar subspecies, *A. cana* ssp. *bolanderi* (Bolander silver sagebrush), occurs in extreme western Nevada and in California and Oregon. It is more canescent than ssp. *viscidula* and grows on poorer drained, usually more alkaline soils than does *viscidula* (Beetle 1960).

Artemisia filifolia Torr. (sand or oldman sagebrush)

Sand sagebrush is a round, freely branching shrub up to 1.5 meters tall (fig. 11). Young branches are covered with a canescent pubescence while the older stems are covered by a dark-gray or blackish bark.

The filiform silvery-white canescent leaves are 3 to 8 cm long, less than 0.5 mm wide, entire or ternately divided into filiform divisions, and are often fascicled (fig. 12a).

Numerous, nodding heads containing 2 or 3 fertile, pistillate ray flowers and 1 to 6 perfect but sterile disc flowers are arranged into leafy, narrow panicles. Each head is subtended by 5 to 9 canescent involucral bracts. Both the receptacle and achenes are glabrous. Flowers bloom during August and September. Seed ripens from October to December. Cleaned seed averages 6,910 per gram (3,135,000 per pound).

Hybridization.--Sand sagebrush has a chromosome number of $2n = 18$ (McArthur and Pope 1977). It is a distinctive taxon that is not known to hybridize with other *Artemisias*. Ecotypic selection and subsequent hybridization and development might be possible. Hall and Clements (1923) suggested that birdfoot sagebrush (*A. pedatifida*)

Figure 11.--Sand sagebrush (A. filifolia) growing near Moccasin, Mohave Co., Arizona.

is the closest ally to sand sagebrush. Birdfoot sagebrush is a low perennial subshrub with limited distribution on dry plateaus and ridges in Wyoming and Idaho, and possibly in Montana. In gross morphology, sand sagebrush and birdfoot sagebrush little resemble one another, but their floral characteristics are quite similar. Their distributions do not presently overlap and no intermediates between the two have been found.

Distribution and habitat.--Sand sagebrush is an excellent indicator of sand and is probably the most widespread shrub on sand dunes and sandhills from Nebraska to Arizona (Hall and Clements 1923). It occurs from Nevada and Utah east to Wyoming and western Nebraska and south to Texas, Arizona, and Chihuahua, Mexico.

Use.--The browse value of sand sagebrush depends on where it grows. It is seldom eaten in grasslands where other food is adequate, but in more arid, desert regions, it is often heavily used (Hall and Clements 1923). This species helps prevent wind erosion by helping to stabilize light sandy soils.

Artemisia frigida Willd. (fringed sagebrush[3])

Fringed sagebrush is a fragrant, aromatic, mat-forming perennial subshrub 2 to 5 dm tall (fig. 13), the lower woody stems are spreading and often much branched. Adventitious rooting is common when stems contact the soil. The upper herbaceous stems are erect and leafy. The whole plant is densely silvery-canescent.

The numerous small silky-canescent leaves are 6 to 12 mm long, and are 2 or 3 times pinnately divided.

This species has a deep perennial taproot with numerous extensive laterals that help it withstand drought. This root system is also useful in stabilizing gullies and preventing soil erosion.

Numerous small flower heads are borne in nodding racemes or open panicles (fig. 12b). Small, densely hairy involucral bracts occur in several series around each flower head. Each head contains 10 to 17 outer, seed-producing, pistillate, ray flowers and numerous (25 to 50) tubular-funnelform, perfect, seed-producing disc flowers. Flower receptacles are densely villous.

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[3]Also called estafiata, prairie sagewort, fringed wormwood, pasture sagebrush, Arctic sagebrush, mountain sagebrush, wild sagebrush, and worm sagebrush.

Figure 12.--Artemisia *species. (A)* A. filifolia, *Culture U7, Kanab, Kane Co., Utah (0.8X). (B)* A. frigida, *Culture U8, Soldier Summit, Wasatch Co., Utah (1.1X). (C)* A. spinescens, *McArthur 115, Ferron, Emery Co., Utah (0.9X). (D)* A. tripartita *ssp.* tripartita, *Culture U1, Blue Lake, Humboldt Co., Nevada (1.0X).*

Figure 13.--Fringed sagebrush (A. frigida) growing at Black Mesa, Gunnison Co., Colo.

Fringed sagebrush blooms from July at high elevations to November at lower elevations. Seed matures between September and December. Cleaned seed averages 8,545 per gram (3,875,000 per pound).

Hybridization.--Fringed sagebrush is known only as a diploid, $2n = 18$ (Mulligan and Cody 1972; McArthur and Pope 1977). Numerous ecotypes of *A. frigida* are known over its broad range. It is not known to hybridize with other *Artemisias*.

Distribution and habitat.--Fringed sagebrush is probably the most widely distributed and abundant species of *Artemisia*. Its range extends from Mexico northward through most of the western United States and western Canada into Alaska and Siberia (USDA Forest Service 1937).

Fringed sagebrush is a common plant of the high plains along the eastern slope of the Rocky Mountains, but also occurs in valleys and mountains. It is most abundant in the eastern and northern parts of its range. This species ranges from low, semidesert valleys to more than 3,350 meters (11,000 feet) elevation throughout the Rocky Mountain and Intermountain regions.

Fringed sagebrush inhabits a wide variety of sites. Most typically, it grows in full sunlight in dry, coarse, shallow soils. On winter ranges in western Utah and eastern Nevada, fringed sagebrush may occur in dense stands along shallow depressions that collect moisture from summer rains. In such areas, it is frequently associated with winterfat (*Ceratoides lanata*), shadscale, and rabbitbrushes (*Chrysothamnus* spp.). On plains, foothills, and mountain slopes, this species may be associated with a variety of grasses and forbs as well as with various shrubs such as big sagebrush, Bigelow sagebrush, sand sagebrush, and especially in overgrazed areas, with broom snakeweed. It is a common understory plant in ponderosa pine (*Pinus ponderosa*) in several western States.

Use.--The forage value of fringed sagebrush varies considerably with location and season. Its value as browse is highest in late fall, winter, and early spring on western ranges where it is eaten readily by big game and livestock (USDA Forest Service 1937). It is also important food for sage grouse (Wallestad and others 1975). In other areas, such as the grasslands of the Northwest and Great Plains, fringed sagebrush may be less palatable and occasionally invades deteriorated grasslands. However, on the Great Plains, fringed sagebrush is an important winter antelope food, and is used to a lesser extent the year round (E. F. Schlatter, letter 12/1/77).

This species has strong reproductive qualities and is a good pioneer shrub for stabilizing disturbed areas. It has excellent reproduction from seed, and young plants or segments of old plants are readily transplanted in early spring. Fringed sagebrush has some value as a medicinal plant (Hall and Clements 1923).

Artemisia longiloba (Osterhout) Beetle (alkali sagebrush)

Alkali sagebrush is a low shrub up to 4.5 dm tall. It has lax, spreading stems that frequently layer. The bark is dark brown to black on the older stems. The whole plant has a dark gray-green appearance (Beetle 1960).

Leaves on the vegetative stems are broadly cuneate, up to 2 cm long, and are deeply 3-lobed. Leaves of the flowering stems are similar but smaller on the upper part of the plants. Crushed foliage emits a pungent odor similar to that of camphor, in the spring, and to hydraulic fluid in the fall (Brunner 1972).

This species is readily distinguished from other low sagebrushes by its large heads and early blooming period (Beetle 1959) (fig. 14). Its heads contain 6 to 11 disc flowers and are 3 to 5 mm broad as opposed to 3 mm or less for other low sages. Alkali sagebrush blooms approximately a month earlier than other low sagebrushes. It flowers during mid-June to mid-July and its seed ripens in August. Cleaned seed averages 5,850 per gram (2,655,000 per pound).

Hybridization.--The chromosome number of *A. longiloba* is $2n = 18$ (McArthur and Pope, data on file at the Shrub Sciences Laboratory, Provo, Utah). Natural hybrids are not known, probably because this species flowers earlier than associated sagebrushes.

Beetle (1960) points out that this species has in the past been confused with *A. cana* because of its large heads; with *A. tridentata* because of its broadly cuneate, 3-lobed leaves; and with *A. arbuscula* because of its dwarf size.

Figure 14.--Alkali *sagebrush* (A. longiloba) *growing at Wahsatch Station, Summit Co., Utah. Note the large flower heads.*

Figure 15.--Fenceline contrast which illustrates sheep browsing on alkali sagebrush (A. longiloba) in Echo Canyon, Summit Co., Utah.

Distribution and habitat.--Unlike other sagebrushes, alkali sagebrush characteristically grows in heavy, highly impermeable soils derived from highly alkaline shales, but also it is frequently found on the lighter, limy soils. It occurs between 1,800 and 2,450 meters in elevation (5,900 to 8,000 feet) over 1,325,000 hectares (5,120 square miles) along the foothills of the ranges forming the Continental Divide from southwestern Montana, south through Wyoming to northwestern Colorado, and scattered westward to Utah, Nevada, Idaho, and Oregon (Beetle 1960).

Use.--Beetle (1960) reports that alkali sagebrush ranges are often used for lambing grounds. We have found this shrub heavily grazed in Echo Canyon, Utah, and around Evanston, Wyoming (fig. 15). In this area *A. longiloba* is referred to as "sweet sage." Brunner (1972) reported this species is not heavily used by browsing animals or sage grouse in Nevada.

Alkali sagebrush may be useful in rehabilitating basic mine spoils like those produced from oil shale works. We have observed it invading road cuts in Echo Canyon, Utah, and borrow pits near Kemmerer, Wyoming.

Artemisia nova Nelson (black sagebrush)

Black sagebrush is a small, spreading, aromatic shrub 1.5 to 4.5 dm tall with a dull grayish-tomentose vestiture that causes most populations to appear darker than big sagebrush and low sagebrush (fig. 16). However, some forms may be as light in color as *A. tridentata* or *A. arbuscula* (Beetle 1960). Numerous erect branches arise from a spreading base, but this shrub had not been observed to layer or stump sprout (Beetle 1960). However, we noted some layering of black sagebrush on a roadcut near Kolob Reservoir, Washington Co., Utah.

Typical leaves are evergreen, cuneate, viscid from a glandular pubescence, 0.5 to 2 cm long, 2 to 8 mm wide, and 3-toothed at the apex (fig. 5c). The uppermost leaves, particularly on the flowering stems, may be entire.

Flower heads are grouped into tall, narrow, spikelike panicles that extend above the herbage (figs. 5c, 16, 17). The inflorescence stalks are red-brown and persistent. The heads usually contain from 3 to 5 disc flowers with corollas 1.8 to 3 mm long. The 8 to 12 involucral bracts are greenish-yellow and nearly glabrous.

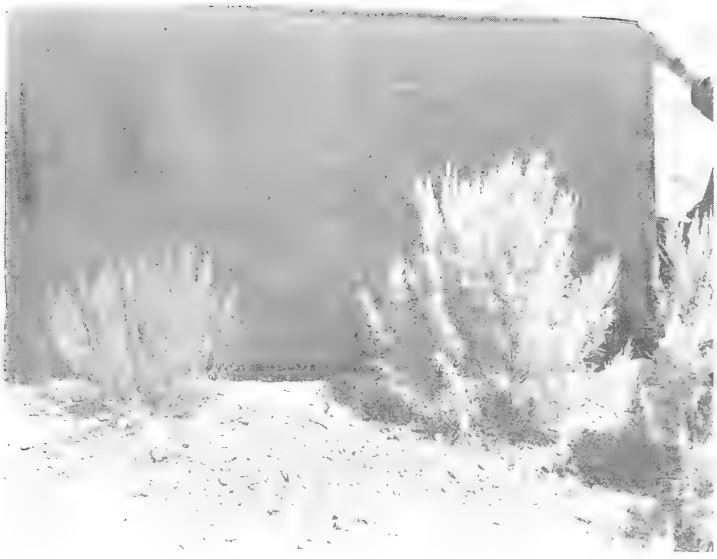

*Figure 16.--Four-year-old transplants of black sagebrush (*A. nova*), left, and basin big sagebrush (*A. tridentata ssp. tridentata*), right. Specimens growing at an adaptation plot near Ephraim, Sanpete Co., Utah.*

The principal difference between black sagebrush and low sagebrush is that low sagebrush has 5 to 11 flowers per head, 10 to 15 canescent involucral bracts, and is light in color. Black sagebrush has fewer flowers per head (3 to 5), 8 to 12 glabrous involucral bracts, and is usually darker in color. Also, the flower stalks of black sagebrush are denser, much darker, and more persistent than those of low sagebrush (Ward 1953).

Black sagebrush flowers from August to mid-September, and seeds mature in October and November. Cleaned seed averages 2,000 per gram (907,000 per pound) (Plummer and others 1968).

Insect galls are numerous on this species, but rust diseases are less common (Beetle 1960).

Hybridization.--Both diploid ($2n$ = 18) and tetraploid ($2n$ = 36) forms of black sagebrush have been found (Ward 1953; McArthur and Plummer 1978). Beetle (1960) has found evidence of *A. nova* hybridizing with *A. bigelovii*, *A. tridentata* ssp. *tridentata*, and *A. tridentata* ssp. *vaseyana*. Crossing between black sagebrush and basin big sagebrush is fairly common wherever they occur together. The cross with mountain big

*Figure 17.--Black sagebrush (*A. nova*) growing in shallow, stony soil at Clay Hills Mesa, San Juan Co., Utah.*

sagebrush is much less common and occurs only at scattered locations. This is as expected because black sagebrush is commonly associated with basin big sagebrush but only occasionally with mountain big sagebrush.

Although black sagebrush is treated in this paper as a separate species, as was done by Beetle (1960), some authorities consider both black and low sagebrush to be subspecies of big sagebrush (Hall and Clements 1923; Davis 1952; Harrington 1954), while Ward (1953) considers black sagebrush to be a subspecies of *A. arbuscula*. The indication that both black sagebrush and low sagebrush can apparently hybridize with big sagebrush indicates a close affinity of these members of section *Tridentatae*.

Distribution and habitat.--Black sagebrush covers approximately 11,220,000 hectares (43,301 square miles) in the 11 western States (Beetle 1960). It is most abundant at elevations from 1,500 to 2,400 meters (4,900 to 7,900 feet) and normally grows on drier, more shallow stony soil than basin or mountain big sagebrush (fig. 17) (Beatley 1976). Type locality is listed as "Medicine Bow, Carbon County, Wyoming" (Abrams and Ferris 1960).

Use.--Black sagebrush is generally considered highly palatable especially to sheep, goats, antelope, and sage grouse. It is held in high regard as browse for sheep, goats, deer, and antelope on winter ranges in Utah, Colorado, and New Mexico. In some areas it is browsed by cattle, but cattle show less preference for it than other animals. Palatability seems to vary with color. In Nevada, a gray-green form is heavily grazed; whereas, a darker glossy-green form is much less grazed (Brunner 1972). That palatability varies with color forms has been supported by some of our work (Stevens and McArthur 1974).

Black sagebrush is an aggressive natural spreader from seed and provides good ground cover for stabilizing soil. Under proper management, stands depleted by heavy grazing recover within less than 10 years. Some large areas in Nevada formerly occupied by black sagebrush have been invaded by Utah juniper (*Juniperus osteosperma*) and single leaf pinyon pine (*Pinus monophylla*).

Artemisia pygemaea Gray (pigmy sagebrush)

Pigmy sagebrush is a dwarf, depressed, evergreen, cushionlike shrub less than 2 dm tall (fig. 18). Bark on older stems becomes dark brown and fibrous. On young branches the bark is nearly white to straw-colored and somewhat puberulent.

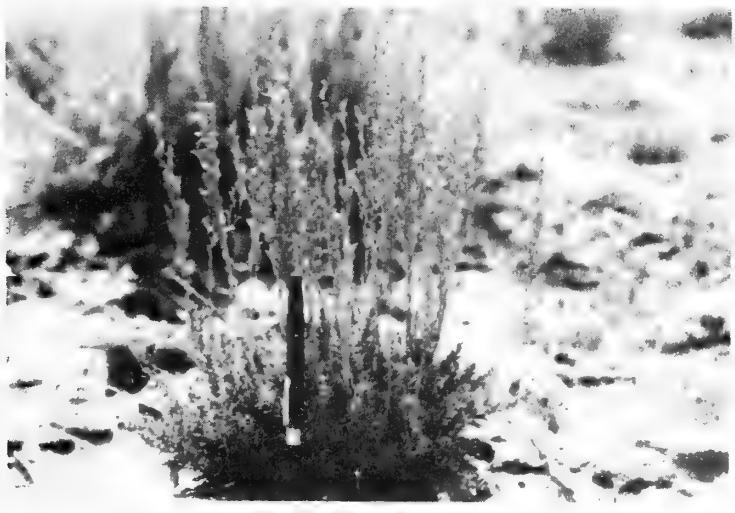

*Figure 18.--Pigmy sagebrush (*A. pygmaea*) growing at the Snow Field Station.*

*Figure 19.--Pigmy sagebrush (*A. pygmaea*) growing south of Ouray, Uintah Co., Utah.*

Leaves on the vegetative stems are green, nearly glabrous, viscidulous, 2 to 4 mm wide, 2 to 8 mm long and are pinnatifided with 3 to 11 lobes, or sometimes may be only toothed. Leaves on the flowering branches are usually reduced and may be entire.

Heads with 3 to 5 disc flowers are arranged into spikelike inflorescence. Ray flowers are lacking. Twelve to 18 greenish-yellow bracts subtend each head. Achenes are glabrous. Flowers bloom in August and September, and seed matures in October. Seeds are large for *Artemisia*. Cleaned seed average 970 per gram (440,000 per pound).

Hybridization.--Both diploid ($2n$ = 18) and tetraploid ($2n$ = 36) forms of *A. pygmaea* are known (Ward 1953; McArthur and Pope, data on file at the Shrub Sciences Laboratory, Provo, Utah).

Distribution and habitat.--Pigmy sagebrush is limited to calcareous soils in desert areas over approximately 5,000 hectares (21 square miles) from eastern Utah to western Nevada, and northern Arizona (Ward 1953; Beetle 1960; McArthur and Plummer 1978) (fig. 19). In Nevada, this species is often associated with the halophytic *C. nauseosus* ssp. *consimilis*. Some fairly large stands occur with black sagebrush in Utah. Its type locality is Fish Creek, near Eureka, Nevada.

Use.--Because of its scarcity and small size, this species has little value as browse. It does, however, provide important ground cover in the dry, alkaline areas where little else will grow. It establishes readily by transplanting divided plants. Although it spreads well from naturally dispersed seed, artificial planting of seed has not been successful.

Artemisia rigida (Nutt.) Gray (stiff or scabland sagebrush)

Stiff sagebrush is a low, pungently aromatic shrub with thick, rigid, somewhat brittle branches up to 4 dm high (fig. 20). It is not known to rootsprout or layer. The deciduous, silvery-canescent, spatulate leaves are mostly 1 to 4 cm long and deeply divided into 3 to 5 narrowly linear lobes. Occasionally some leaves are linear and entire (fig. 21).

Inflorescence is a leafy spike with heads sessile or in small clusters in the axils of their subtending leaves, which generally are all longer than the heads (fig. 22a). The campanulate involucre is 4 to 5 mm long with numerous, canescent bracts. Each head consists of 5 to 16 perfect disc flowers. Flowering occurs during September and October; seeds ripen in November. Seeds number 1,210 per gram (550,000 per pound).

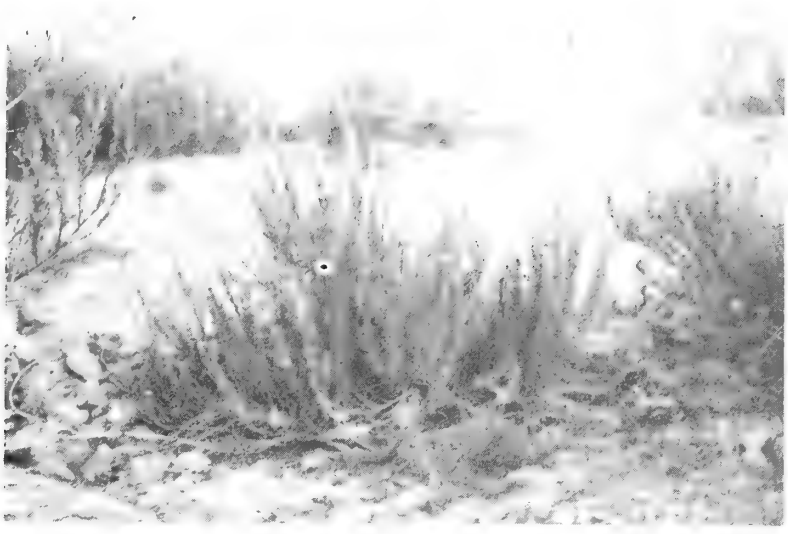

*Figure 20.--Scabland sagebrush (*A. rigida*) growing at the Snow Field Station. The ruler is 30 cm long.*

Hybridization.--Both diploid ($2n$ = 18) and tetraploid ($2n$ = 36) forms of stiff sagebrush are known (Ward 1953; McArthur and Plummer 1978). This species resembles *A. tripartita* somewhat in its small size, silvery pubescence, and the deeply, narrowly lobed leaves, but may be distinguished by the spikelike inflorescence, large leafy bracts that subtend the heads, and the deciduous leaves.

Distribution.--Stiff sagebrush occurs in dry rocky scablands in the Columbia and Snake River basins and spills over into the northern end of the Great Basin. It grows at elevations from 910 to 1,520 meters (3,000 to 5,000 feet) in Idaho, central and eastern Oregon, and central and eastern Washington. It is adapted to the rocky scablands of these States and fills an ecological niche similar to that of *A. arbuscula* in the areas where it is found (Ward 1953).

Although several authors (Hall and Clements 1923; Davis 1952; Hitchcock and others 1969) include western Montana in the distribution of stiff sagebrush, neither Ward (1953) nor Beetle (1960) do. Ward (1953) claims the report of *A. rigida* from western Montana is probably a result of errors in identification. He identifies the specimens in this area as *A. tripartita*.

Figure 21.--Leaves and branches of scabland sagebrush (A. rigida).

Figure 22.--Artemisia taxa. *(A)* A. rigida, *Edgerton 1-75, LaGrande, Union Co., Oregon (1.4X). (B)* A. tridentata *ssp.* tridentata, *Culture U77, Enterprise, Washington Co., Utah (0.6X). (C)* A. tridentata *ssp.* vaseyana, *McArthur 697, Provo, Utah Co., Utah (0.9X). (D)* A. tridentata *ssp.* wyomingensis, *McArthur and Plummer 394, Big Piney, Sublette Co., Wyoming (0.9X).*

Use.--Because of its scant foliage and stiff branches, stiff sagebrush has little value for browse, except for sheep (Hall and Clements 1923). This species provides important cover on the poor, rocky soils where it grows. It appears to have a wider range of adaptation than is indicated by its present natural range of occurrence, thus giving it potential use in reclamation of disturbed sites.

Artemisia rothrockii Gray (timberline sagebrush)

Timberline sagebrush is a consistently low-growing, evergreen, flat-topped shrub from 1 to 8 dm tall (fig. 23). Its appearance in the field closely resembles some forms of mountain big sagebrush. Timberline sagebrush, however, has a more pronounced, consistent tendency to layer and has thicker, darker, more or less viscid leaves, which give the plant a dark green color.

Leaves on the vegetative branches are often 10 mm broad and 3 cm long (Beetle 1960) but range in size from 2 to 51 mm wide and 0.5 to 5 cm long. The lower leaves are mostly broadly cuneate or fan shaped and 3-toothed or lobed (fig. 5d). The upper leaves, however, may be entire and linear to lanceolate or oblanceolate. The foliage emits a mildly aromatic aroma when crushed.

Flower heads occur singly or occasionally 1 to 3, in short interrupted spike or racemelike inflorescences. Each head contains 6 to 16, rarely as many as 20, disc flowers. Ray flowers are lacking. The 10 to 14 involucral bracts are often brown or purplish. Achenes are granuliferous. Flowers bloom during August and September. Seeds mature during September and October. Plantings of this sage in valley lowlands of central Utah have bloomed profusely, but none of the plants produced mature seed.

Hybridization.--Artemisia rothrockii occurs in diploid ($2n = 18$), tetraploid ($2n = 36$), hexaploid ($2n = 54$), and octoploid ($2n = 72$) forms (Ward 1953; McArthur and Plummer 1978). Beetle (1960) suggests this species may be of hybrid origin from *A. cana*, which it resembles in its strong tendency to layer, large heads and conspicuous bracts, and *A. tridentata*, which it resembles in leaf shape, general habit, and habitat. Our discovery (McArthur and Plummer 1978) that at least some Rocky Mountain forms are diploid does not support Beetle's hybrid ancestry contention. However, the diploid Rocky Mountain material may be an undescribed taxon rather than bona fide *A. rothrockii*.

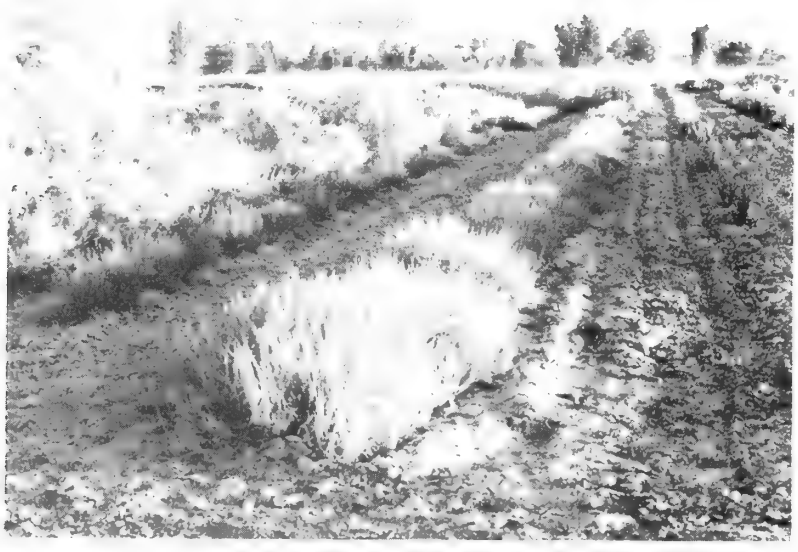

*Figure 23.--A row of timberline sagebrush (*A. rothrockii*) growing at the Snow Field Station, Ephraim, Sanpete Co., Utah.*

Figure 24.--Budsage (A. spinescens) growing near Sevier Lakebed, Millard Co., Utah.

Distribution and habitat.--Timberline sagebrush covers approximately 27,200 hectares (103 square miles) at between 2,600 and 3,350 meters (8,500 and 11,000 feet) in elevation in high mountainous areas of central Colorado, western Wyoming, and the central Sierras of California (Beetle 1960). This species is usually found growing in deep soils along the margins of forests. This species, or a similar undescribed form, is also found in other western States, particularly in the high mountains of Utah, Idaho, and Nevada. *A. rothrockii's* type locality is the Monache Meadows, 2,600 meters (8,500 feet), Sierra Nevada Mountains, Tulare County, California (Hall and Clements 1923; Beetle 1960).

Use.--Timberline sagebrush is a palatable sagebrush, grazed heavily by big game and livestock. It shows potential as low hedge for landscaping.

Artemisia spinescens Eaton (budsage[4])

Budsage is a low, spinescent, pungently aromatic, rounded shrub 1 to 5 dm high (fig. 24). It is profusely branched from the base and has white-tomentose pubescence on young twigs and leaves. This pubescence is grayish and stiff on older branches.

Leaves are small, mostly 2 cm or less in length, including the petiole. Leaves are 3 to 5 palmately parted, with the divisions again divided into 3 linear-spatulate lobes (fig. 12c). Leaves are crowded on the short stems, with those near the apex being smaller and more entire. Unlike most species of *Artemisia*, budsage is deciduous, with the leaves falling by midsummer.

Early in the spring, when budsage first shows signs of breaking dormancy, but before the buds elongate, the bark from the last season's growth can easily be pulled off. At this developmental stage, budsage is sought out by big game and livestock. Sheepmen refer to this condition as "slipping." As early as February or March, new bright-green leaves are produced.

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[4]Also called spring sagebrush and bud sagebrush.

Budsage is well adapted to xeric conditions. It has an extensive root system that grows primarily in the top 15 to 55 cm of soil. Interxylary cork is formed annually over the last year's wood in both the roots and the stem. This layer of cork restricts the upward movement of water to the very narrow zone of wood formed by the current year's growth. The corky tissue develops during early summer and thus helps to prevent excessive water loss during the dormant season (Wood 1966). Many other xerically adapted woody *Artemisias* also have interxylary cork (Moss 1940).

Budsage bears small flower heads (3 to 5 mm long) in glomerate racemes of 1 to 3 heads in leaf axils of the flower branches. Each head contains 2 to 6 fertile, pistillate ray flowers and 5 to 13 perfect but sterile disc flowers with abortive ovaries.

The loose flower heads are held together by long, matted hairs that cover the corolla and especially the achenes. The heads fall from the plant intact, without breaking apart to release the seed. Seeds germinate in some instances, while still in the head (Wood 1966). Good seed production occurs infrequently. The flowers bloom so early in the spring that developing embryos frequently are frozen. Abundant reproduction occurs in years of plentiful seed and favorable moisture.

Terminal and lateral buds of budsage generally expand and begin to elongate in late March and early April during the latter part of the "slipping" period. Blooming normally occurs from the last week in April through the last week in May, although it has been found in bloom as early as late March and as late as mid-June (Wood 1966). Cleaned seed averages 4,855 per gram (2,200,000 per pound).

Although budsage ordinarily begins growth early in the spring and then becomes dormant by early or midsummer, it occasionally may break dormancy in response to late summer storms. The plants then remain green all winter to provide succulent forage throughout the winter and spring.

As a species, budsage is distinguished by its spinescent habit and low variability in involucre and floral characteristics. The harsh environment in which budsage grows has perhaps helped to stabilize this species so that no variants have yet been recognized and named.

Hybridization.--Artemisia spinescens has chromosome numbers of $2n = 18$ and $2n = 36$ (Powell and others 1974; McArthur and Pope 1977). It is not known to hybridize with any other species. Its tetraploid form is thought to be autotetraploid (McArthur and Pope, data on file at the Shrub Sciences Laboratory, Provo, Utah).

Distribution and habitat.--Budsage is a very drought-resistant shrub found on dry, often saline plains and hills from southwestern Montana, central Idaho, and eastern Oregon southward to southeast California, New Mexico, Arizona, and Colorado. Type locality is "Rocky Mountain plains, in arid deserts, toward the north sources of the Platte" (Abrams and Ferris 1960). It is often associated with shadscale, black greasewood (*Sarcobatus vermiculatus*), and other salt-tolerant shrubs. In some areas, it is associated with black sagebrush and basin big sagebrush.

Use.--Budsage is a palatable, nutritious forage plant for upland birds, small game, big game, and sheep in the winter. Generally, it is more palatable in the late winter than during the early winter (Holmgren and Hutchings 1972). During this time it is of tremendous value to the welfare of grazing animals, especially where there is an abundance of dry grass.

Care must be taken in grazing budsage in late winter and early spring. Even light grazing during this period is detrimental, and continual, heavy grazing may eliminate budsage from the area (Holmgren and Hutchings 1972).

*Figure 25.--Large specimen of basin big sagebrush (*A. tridentata *ssp.* tridentata*) growing near LaSal, San Juan Co., Utah.*

Artemisia tridentata Nutt. (big sagebrush[5])

Big sagebrush is a highly polymorphic species with numerous ecotypes and biotypes. Three subspecies (*tridentata, wyomingensis,* and *vaseyana*) are generally recognized at the present time (Beetle 1960; Beetle and Young 1965), and will be discussed individually following the general presentation of the species.

Big sagebrush is composed of aromatic, evergreen shrubs ranging in size from dwarf to tall, arborescent forms up to 4.5 m tall (fig. 25). The lower forms generally have several main stems arising from the base, whereas the tall forms often have a single short trunk. Older branches are covered with a gray to brown or black shredded bark. Younger branches and leaves have a white to gray tomentum which gives the plants a silvery cast.

Typical leaves are narrowly cuneate or oblanceolate and terminate with 3 blunt teeth at their truncate apexes (fig. 26). However, considerable variation occurs, ranging from linear, entire leaves with rounded to acute apexes to broadly cuneate leaves with varying number of teeth or shallow lobes. The leaves also range in size from 2 mm to 2 cm broad and 1 cm to 6.5 cm long. Normally, leaves on vegetative shoots are more characteristic and less variable than those on flowering shoots. Also, persistent leaves, that is overwintering leaves, are less variable than leaves of the spring growth flush (Winward 1970), which are shed by midsummer.

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[5]Other common names include common sagebrush and black sage.

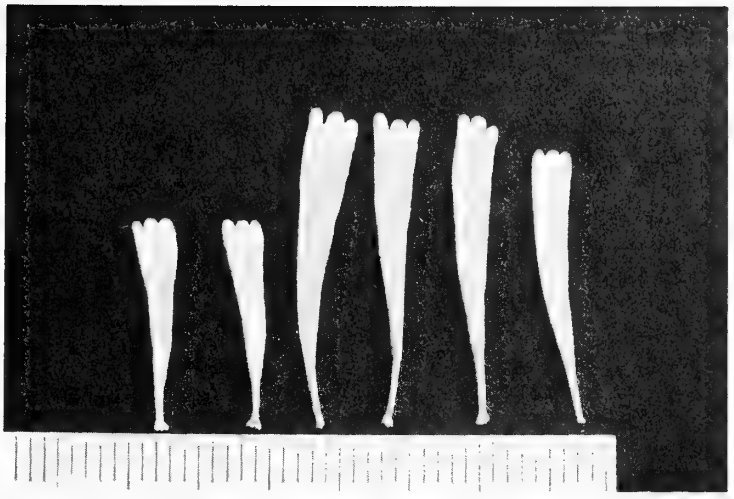


*Figure 26.--Typical leaves of basin big sagebrush (*A. tridentata *ssp.* tridentata*). The scale is in mm.*

Heads of this species contain 3 to 8 disc flowers each and are arranged into leafy panicles with erect or sometimes drooping branches. In some forms, the inflorescence becomes spikate. Blooming occurs from July to October. Seeds (fig. 27) mature in October, November, and December. There are about 5,510 seeds per gram (2,500,000 per pound) (Plummer and others 1968; Deitschman 1974). Big sagebrush plants often live 100 years. Specimens from several sites were found to be more than 200 years old (Ferguson 1964).

Hybridization.--Artemisia tridentata has a basic chromosome number of $x = 9$. Both diploid ($2n = 18$) and tetraploid ($2n = 36$) forms are known (Ward 1953; Taylor and others 1964; Winward 1970; Kelsey and others 1975; McArthur and Plummer 1978; McArthur and Pope, data on file at the Shrub Sciences Laboratory, Provo, Utah). In many cases there is no morphological difference between the diploid and tetraploid plants. In fact they may grow together. Subspecies *tridentata* and *vaseyana* both have diploid, tetraploid, and mixed populations. Subspecies *wyomingensis* is now known only as a tetraploid.

This species readily crosses both intraspecifically and interspecifically (table 2). In their chromatographic work, Hanks and others (1973) found evidence of natural hybridization among the following species and subspecies: *A. tridentata* ssp. *vaseyana* with *A. tridentata* ssp. *tridentata*, *A. arbuscula* ssp. *arbuscula*, *A. nova*, *A. tripartita*

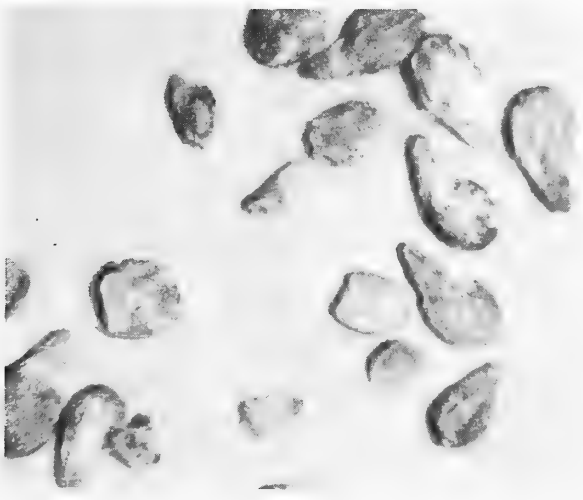


*Figure 27.--Basin big sagebrush (*A. tridentata *ssp.* tridentata*) seed (7X).*

Treatment	Seed produced								
	1974			1975			1976		
	N	$\bar{X} \pm se^2$	Range	N	$\bar{X} \pm se^2$	Range	N	$\bar{X} \pm se^2$	Range
Open pollination	26	1,222±199*	11-3,000	16	1,845±345*	10-4,000	42	1,575±322*	0->5,000
Intrapopulation	25	115±40	0-1,000	26	11±5	0-100	41	77±21	0-500
Interpopulation Bag 1	25	78±24	0-300	14	16±7	0-94	39	31±10	0-250
Interpopulation Bag 2	26	62±14	0-300	14	14±7	0-100	40	24±9	0-300
Control	26	37±12	0-300	10	10±3	0-30	42	12±5	0-200

[1]Taxa involved in hybridization experiments include *A. arbuscula, A. bigelovii, A. cana,* ssp. *viscidula, A. nova, A. pygmaea, A. tridentata* ssp. *tridentata, A. t.* ssp. *vaseyana, A. t.* ssp. *wyomingensis,* and *A. tripartita* ssp. *tripartita.*

[2]The * in the $\bar{X}$ (mean) ± se (standard error of the mean) column indicates a significant difference in the open pollination treatment from all other treatments. None of the other treatments were significantly different, according to the multiple range test ($p<.05$).

ssp. *tripartita,* and *A. cana* ssp. *viscidula; A. tridentata* ssp. *tridentata* with *A. tripartita* ssp. *tripartita* and *A. tridentata* ssp. *wyomingensis.* Beetle (1960) reported finding intermediates between the following: *A. tridentata* ssp. *tridentata* with *A. tridentata* ssp. *vaseyana,* and *A. cana* ssp. *cana* with *A. nova.*

Ward (1953) examined two mixed populations of *A. tridentata* and *A. cana.* In one population the *A. tridentata* was diploid and the *A. cana* was tetraploid. In the other population, *A. tridentata* was tetraploid while the *A. cana* was diploid. The putative hybrids from both populations were tetraploid and blended in with the tetraploid parent.

Because of its plasticity and the apparent ease with which it hybridizes, there are great opportunities for developing improved forms of big sagebrush for different purposes. Controlling the hybridization, however, may prove very difficult.

Distribution and habitat.--Big sagebrush is the most widespread and common shrub of western North America. It is especially common in the Great Basin. This species covers approximately 58,655,000 hectares (226,374 square miles) in the 11 western States (Beetle 1960). It grows in a variety of soils on arid plains, valleys, and foothills to mountain slopes from 500 to 3,400 meters (1,600 to 11,200 feet) and is frequently associated with such shrubs as shadscale saltbush, rubber rabbitbrush, low rabbitbrush, fourwing saltbush, spiny hopsage (*Grayia spinosa*), spiny horsebrush (*Tetradymia spinosa*), winterfat, and broom snakeweed.

Although it is tolerant of quite alkaline as well as quite acid soils, its optimum growth is in deep, fertile, alluvial loams (Sampson and Jesperson 1963).

Although big sagebrush has spread with settlement of the West (Cottam 1961; Christensen and Johnson 1964; Hull and Hull 1974), nevertheless, it was clearly an important and widespread plant before this settlement. As early as the Pleistocene Epoch, sagebrush was already an important part of the Intermountain Flora. Eight to ten thousand years ago, sagebrush dominated large tracts of land in areas where it is still found (Tidwell and others 1972; Van Devender 1977). Vale (1975), quoting from early pioneer and explorer diaries, has shown it was a common western plant prior to 1850.

Big sagebrush and its section *Tridentatae* relatives (table 1) are subject to insect and microbial pests and benefactors--most notably, the sagebrush defoliator moth (*Aroga websteri*). Wide ranging and periodic outbreaks of this insect have caused extensive sagebrush mortality over much of the range of *A. tridentata* and its relatives (Henry 1961; Hall 1965; and personal observations of the authors). However, except on some

*Figure 28.--Basin big sagebrush (*A. tridentata *ssp.* tridentata*) growing with crested wheatgrass (*Agropyron cristatum*) in Pigeon Hollow, Sanpete Co., Utah.*

critical winter game ranges, *Aroga websteri* is not believed to have serious, long-term effects. The moth is subject to insect parasites and predators and does not completely kill off sagebrush stands (Hall 1965). In time sagebrush naturally reinvades its old sites which in the mean time have become more diverse plant communities. During drought periods grasshoppers have been known to defoliate *A. tridentata* (E. F. Schlatterer, letter 12/1/77). Galls of many kinds of flies (Diptera) are found on sagebrush (Hall 1965; Jones 1971; C. F. Tiernan, data on file at the Shrub Sciences Laboratory, Provo, Utah). The effect of the galls is not known. Sagebrush hosts many other insects of various orders. Some of these may protect the plant from disease vectors. Several microbial-induced diseases are known (Krebill 1972). Some of these are widespread and may be locally destructive; however, sagebrush populations are resilient and generally are not significantly affected in the long run. D. L. Nelson (data on file at the Shrub Sciences Laboratory, Provo, Utah) has recently isolated several fungal species of the genera *Verticillium*, *Fusarium*, and *Rhizoctonia* from dying sagebrush in uniform gardens. We have observed similar symptoms (dying desiccated plants) in natural populations. We believe diseases induced by these fungi may be among the most serious sagebrush diseases. Some microbes are likely useful for the vigor and growth of sagebrush. Wallace and Romney (1972) found preliminary evidence that *A. tridentata* formed symbiotic relationships with microbial endophytes to fix atmospheric nitrogen. Williams and Aldon (1976) found endomycorrhizae within *A. tridentata* roots and abundant spores around the roots. Endomycorrhizae, in general, have a beneficial influence on plant growth by promoting nutrient absorption through infected roots (Williams and Aldon 1976). For sagebrush, the beneficial effect is suggestive but not yet proven.

Use.--Artemisia tridentata is one of the more nutritious shrubs on western winter livestock and game ranges. Subspecies *tridentata* has higher protein levels than the other two subspecies (Welch and others 1977). Unfortunately, this species also contains considerable aromatic oil, which may reduce its digestibility (Nagy and others 1964). Nevertheless, because of its widespread abundance, its ability to grow with associated grasses (figs. 4, 28), forbs, and other shrubs and its nutritious nature, big sagebrush is the most important winter forage in foothill areas through much of the West for livestock and big game. Furthermore, the volatile oil content varies with subspecies and accession (Sheehy and Winward 1976; Scholl and others 1977; Welch and McArthur, data on file at the Shrub Sciences Laboratory, Provo, Utah). Perhaps the oil content could be reduced in improved planting stock. It is one of the best shrubs available for use in revegetation of depleted winter game ranges in the Intermountain area (fig. 29) (Plummer 1974).

*Figure 29.--Basin big sagebrush (*A. tridentata *ssp.* tridentata*) that has been seeded after juniper-pinyon control near Fillmore, Millard Co., Utah.*

Palatability of the different populations of this shrub varies widely. Basin big sagebrush (*A. tridentata* ssp. *tridentata*) is generally less palatable than Wyoming big sagebrush (*A. tridentata* ssp *wyomingensis*); both are less palatable than mountain big sagebrush (Hanks and others 1973; Sheehy and Winward 1976). Hanks and others (1973) found that intermediates exhibit considerable variation in their palatability, but are usually preferred to plants of the subspecies *tridentata*. Sagebrush is important food and cover for upland birds. For example, sagebrush was found to comprise 62 percent of the annual diet of sage grouse in Montana (Wallestad and others 1975). Big sagebrush is an important component of antelope diet. Olsen and Hansen (1977) found sagebrush comprised 78 percent of the annual diet for antelope in Wyoming's Red Desert.

Big sagebrush stands are unexcelled in providing ground cover and forage when grazed to maintain a balance between the sagebrush and associated herbs and shrubs (Plummer and others 1968). Because big sagebrush establishes rapidly from both transplanting and direct seeding, it is useful for stabilizing washes, gullies, roadcuts, and other raw, exposed sites.

In the Old West, big sagebrush was commonly used by both Indians and the white settlers for fuel and for construction of shelters. Its wood makes a quick, hot fire, and its branches thatched temporary homes and sheds (Hall and Clements 1923).

Subspecies.--Artemisia tridentata ssp. *tridentata* (basin big sagebrush[6]) is an erect, heavily branched, unevenly topped shrub. This subspecies has undivided, or at least trunklike, main stems. Shrubs range between 1 and 2 meters in height (fig. 30). Some forms, however, may reach 4.5 meters in suitable habitats (fig. 25). Mature shrubs of this subspecies are the largest members of the big sagebrush complex. The evergreen, vegetative leaves are narrowly lanceolate, up to 5 cm long by 5 mm wide, and typically 3-toothed at the apex (fig. 22). The leaves of the flowering stems, however, gradually become smaller and may be linear or oblanceolate and entire. Winward (1970) found the average length-to-width ratio of persistent leaves on specimens from Idaho to be 5.6. The gray-canescent foliage possesses a strongly pungent, aromatic odor. Flowering stems arise throughout the uneven crown and bear numerous flower heads in erect, leafy

[6]Other common names include common sagebrush, common big sagebrush, narrowleaf big sagebrush, and valley big sagebrush.

*Figure 30.--Two even-aged plants representing ecotypes of basin big sagebrush (*A. tridentata *ssp.* tridentata*) growing at the Snow Field Station. The form on the left was transplanted from Paradise Valley, Humboldt Co., Nevada; the one on the right was transplanted from the Jackson Mountains, Humboldt Co., Nevada. The ruler in the center foreground is 30 cm long.*

panicles. The heads contain 3 to 6 small yellowish or brownish, trumpet-shaped, perfect-disc flowers. The narrowly campanulate involucre consists of canescent bracts 3 to 4 mm long and about 2 mm wide that form 4 to 5 overlapping series around each head. The outermost bracts are less than a fourth as long as the innermost bracts. Flowering occurs from late August to October. Seed matures depending on site from October to November. Basin big sagebrush is probably the most abundant shrub in western North America on lowland ranges. It normally occurs on dry, deep, well-drained soils on plains, valleys, and foothills below 2,130 meters (7,000 feet) elevation. Above this elevation, subspecies *vaseyana* and occasionally subspecies *wyomingensis* are more prevalent. Vigorously growing basin big sagebrush is considered indicative of productive ranges because it often grows in deep, fertile soil. This subspecies has generally been regarded as intolerant of alkali, but there are ecotypes that grow in relatively high alkalinity in association with such alkali-tolerant plants as black greasewood, shadscale saltbush, and saltgrass (*Distichlis stricta*). Plants with strikingly reflexed drooping branches of inflorescence are found throughout the range of subspecies *tridentata*. These have been termed *A. tridentata* ssp. *tridentata* f. *parishii* (Beetle 1959). This form may be environmentally induced because some ssp. *vaseyana* populations of central Nevada also have drooping inflorescences in some years (E. F. Schlatterer, letter 12/1/77).

Artemisia tridentata ssp. *vaseyana* (mountain big sagebrush) is normally a smaller shrub than basin big sagebrush. Its main stem is usually divided at or near the ground, and it tends to have a spreading, evenly topped crown (fig. 31). The vegetative branches are usually less than 1 meter high and frequently layer at their bases. There are, however, ecotypes at lower elevations that may reach about 2 meters in height. The persistent vegetative leaves are broadly cuneate to spatulate and are characteristically wider than those of both basin and Wyoming big sagebrush (fig. 22c). When looking down at this shrub, the terminal leaves on each twig appear to be distinctly whorled (fig. 32). Subspecies *tridentata* does not show this trait. However, ssp. *wyomingensis* shows the trait to some extent. Normally, the leaves are 2 cm long, 5 mm broad, but in form *spiciformis* may reach 6.5 cm long and 2 cm broad. Leaf length-to-width rates for typical persistent *vaseyana* leaves average 4.0 while that of form *spiciformis* averages 3.5 (Winward 1970). Crushed leaves emit a rather pleasant mintlike fragrance in contrast to the more pungent odor of both basin and Wyoming big sagebrush. Flower heads are arranged into narrow, often dense panicles or spikes. The heads contain 5 to 8 trumpet-shaped, perfect-disc flowers. The broadly campanulate involucre consists of numerous canescent overlapping bracts, 5 mm long and 3 to 4 mm wide. The outermost bracts are less than half as long as the innermost. Some strains of mountain big sagebrush start blooming as early as July and thus may be in bloom up to 6 weeks earlier than either basin or Wyoming big sagebrush (Hanks and others 1973). Seed

*Figure 31.--An even-topped mountain big sagebrush (*A. tridentata *ssp.* vaseyana*) growing in the Targhee National Forest, Sublette Co., Wyoming.*

*Figure 32.--Big sagebrush leaves seen from above. Specimens growing at the Snow Field Station. (A) The whorled terminal leaves of mountain big sagebrush (*A. tridentata *ssp.* vaseyana*) transplanted specimen from Ephraim Canyon, Sanpete Co., Utah. (B) The contrasting nonwhorled appearance of basin big sagebrush (*A. tridentata *ssp.* tridentata*) transplanted from Dog Valley, Juab Co., Utah.*

*Figure 33.--Wyoming big sagebrush (*A. tridentata *ssp.* wyomingensis*) growing near Daniel, Sublette Co., Wyoming.*

matures from September through October. In the Intermountain West, mountain big sagebrush occurs in the upper elevational range of the big sagebrush zone in deep, well-drained soils on mountain slopes from below 1,400 meters (4,600 feet) for f. *xericensis* and at elevations over 3,000 meters (9,800 feet) for f. *spiciformis* (Beetle and Young 1965; Winward 1970). The form *xericensis* is unevenly topped and grows in relatively dry sites similar to basin and Wyoming big sagebrush. In Idaho, this form is known to occur between 780 to 1,400 meters (2,600 to 4,600 feet). Chromatographically, cytologically, and phenologically, *xericensis* most closely resembles and is considered to be a form of ssp. *vaseyana* (Winward 1970; Hanks and others 1973; Winward and Tisdale 1977). The form epithet "*xericensis*" has not been validly published. Winward (1970) used the term. Later, he and Tisdale (1977) merely called this "X big sagebrush." Hanks and others (1973) used an analogous term, low elevation *vaseyana*. Form *spiciformis* has larger flower heads and leaves than typical *vaseyana* and is found at higher elevations, usually over 2,130 meters (7,000 feet) in the cooler, more mesic sites. *Vaseyana* grows in slightly acid to slightly alkaline soils (Welch and McArthur, data on file at Shrub Sciences Laboratory, Provo, Utah). Unlike ssp. *tridentata*, *vaseyana* is rarely associated with any of the saltbushes.

Artemisia tridentata ssp. *wyomingensis* (Wyoming big sagebrush) is somewhat intermediate in distribution, ecology, and morphology between basin big sagebrush and mountain big sagebrush. Occasionally, all three subspecies may be found growing together. Whenever it is found associated with ssp. *tridentata*, ssp. *wyomingensis* is growing in the poorer, more shallow soils (Beetle and Young 1965). Subspecies *wyomingensis* is a low shrub usually less than 1 meter in height. It has an uneven top with flower stalks arising throughout the crown like ssp. *tridentata* (fig. 33). Its main stems branch at or near the ground level like ssp. *vaseyana*, but it does not layer. Leaves are 1 to 2 cm long, narrowly cuneate to cuneate (fig. 22d), and have an average length-to-width ratio of about 3:1 for the persistent leaves (Winward 1970). Flower heads contain 3 to 8 disc flowers and are arranged into panicles narrower than the paniculate inflorescence of *tridentata* and wider than the spicate inflorescence of *vaseyana* (Beetle and Young 1965; Winward and Tisdale 1977). Flowering and seed ripening take place later than *vaseyana* and earlier than *tridentata*. This subspecies may have arisen from hybridization between ssp. *tridentata* and *vaseyana* (Hanks and others 1973) or ssp. *tridentata* and *A. nova* (Winward 1975). Wyoming big sagebrush grows throughout the Intermountain region (fig. 34). It is particularly abundant east of the Continental Divide in Montana, Wyoming, and parts of Colorado in dry, shallow, gravelly soil, usually from 1,500 to 2,100 meters (5,000 to 7,000 feet) (Beetle and Young 1965). In Idaho, this subspecies is found from 760 to 1,980 meters (2,500 to 6,500 feet) in the hotter, drier portions of the State (Winward 1970).

*Figure 34.--A large stand of Wyoming big sagebrush (*A. tridentata *ssp.* wyomingensis *growing near its type location, Daniel, Sublette Co., Wyoming. Note size contrast to basin big sagebrush of figure 25.*

Artemisia tripartita Rydb. (threetip sagebrush)

Threetip sagebrush is a rounded, evergreen shrub up to 2 meters high. It may have a simple, trunklike main stem or several branches arising from the base. The bark on young branches is canescent, but becomes shredded and grayish, light brown to dark brown or black on older stems. This species can layer, sometimes sprouts back after a burn, and may sprout from the stump following herbicide treatments (Beetle 1960; Pechanec and others 1965; Schlatterer 1973).

Leaves of the vegetative branches are canescent, 0.5 to 4 cm long, and typically deeply divided into 3 linear or narrowly linear-lanceolate lobes (fig. 12d), which in turn may be 3-cleft. Some of the upper leaves are often entire. Crushed foliage emits a pungent odor.

Flower heads contain 3 to 11 disc flowers and are normally arranged into panicles. Ray flowers are lacking. Each head is subtended by 8 to 12 canescent involucral bracts. Achenes are resinous-granuliferous. Blooming occurs from July to September. Cleaned seeds average 5,490 per gram (2,490,000 per pound).

Hybridization.--Artemisia tripartita occurs in both diploid ($2n$ = 18) and tetraploid ($2n$ = 36) forms (Ward 1953; McArthur and Pope, data on file at the Shrub Sciences Laboratory, Provo, Utah). Some evidence of natural hybridization involving this species and other shrubby *Artemisia* has been found (Beetle 1960; Hanks and others 1973).

Distribution and habitat.--Threetip sagebrush covers approximately 3,370,000 hectares (13,002 square miles) in the Northern Rocky Mountains and Great Basin States from British Columbia south through Montana and Wyoming to Colorado and west to Washington, Oregon, northern Nevada, and northern Utah at elevations between 900 to 2,750 meters (3,000 to 9,000 feet) (Beetle 1960). In some places, particularly in Idaho, this species occurs between the lower, hot, dry sites dominated by Wyoming big sagebrush and the higher, cooler sites dominated by mountain big sagebrush (Schlatterer 1973).

Use.--Threetip sagebrush is a vigorous seeder, but unfortunately some forms are not particularly palatable. Beetle (1960) reported it was of low palatability for both livestock and game, and Brunner (1972) observed that it was never grazed in

Nevada. However, a form near Salmon, Idaho, is palatable to deer. The form near Salmon is intermediate in morphology between *A. tripartita* and *A. tridentata* spp. *wyomingensis* (E. F. Schlatterer, letter 12/1/77).

Subspecies.--Artemisia tripartita ssp. *rupicola* (Wyoming threetip sagebrush) is a dwarf shrub with decumbent branches that rarely grow over 1.5 dm tall. It is frequently found layering and may have a crown spread of 3 to 5 dm (Beetle 1960). Leaves of the vegetative branches are often 3 cm long and deeply divided into linear lobes, each at least 1 mm wide (Beetle 1959, 1960). Flower heads bear 3 to 11 disc flowers and are arranged into leafy, narrowly racemose panicles. Flowers bloom in late August and September. Seed ripens in October. Wyoming threetip sagebrush has a rather limited range. It occurs on rocky knolls from 2,430 to 2,740 meters (7,000 to 9,000 feet) in elevation in central and southeast Wyoming (Beetle 1960). Brunner (1972) reported this subspecies also occurs in southern Oregon but has not yet been found in Nevada. It typically grows on sites adjacent to those of mountain big sagebrush.

Artemisia tripartita ssp. *tripartita* (tall threetip sagebrush) is a freely branching shrub up to 2 meters high. It can layer easily when the conditions are right, but is seldom found layering in the field. After burning, it may stump-sprout (Beetle 1960). Leaves of the vegetative branches are 1.5 to 4 cm long and deeply divided into 3 linear lobes less than 1 mm wide. The lobes may be further divided (Beetle 1959, 1960). Flower heads bear 4 to 8 disc flowers and are arranged into panicles that may sometimes be reduced to a spicate form. Flowers bloom in late August and September. Seeds ripen in October. This subspecies occurs in dry, well-drained soils at 900 to 2,300 meters (3,000 to 7,500 feet) elevation from British Columbia south through Washington to northern Nevada and eastward to northern Utah and western Montana. Its type locality is listed as "Plains of Rocky Mountains" (Beetle 1960).

Artificial hybridization in section *Tridentatae* of *Artemisia*

Our experiments in hybridizing *Artemisia* section *Tridentatae* were undertaken with plant improvement in mind (McArthur and Plummer 1974; McArthur and Pope 1975). The section contains many taxa with different combinations of traits. We think some of these traits such as growth form, palatability, adaptation, protein and volatile oil content, and vegetative spread might be brought together in various combinations for the land manager's benefit.

The experiments were designed to determine: (1) Does hybridization occur and if so (2) can it be controlled, and (3) to what extent are section *Tridentatae* plants self-fertile? These questions are, of course, all interrelated. We have referred to evidence for hybridization under each species that has been discussed. This evidence is in the form of morphological and chemical intermediates. More definite evidence is available. We have found triploid and pentaploid seedlings at the Snow Field Station (McArthur and Pope, data on file at the Shrub Sciences Laboratory, Provo, Utah). The best explanation for their occurrence is that plants of different polyploid levels hybridized. The *Tridentatae* are mostly wind pollinated, a condition that gives opportunity for hybridization. Estes (1968) presented solid cytological, morphological, and pollen stainability (an indication of pollen viability) data for hybridization in the *A. ludoviciana* complex. Estes' (1968) hybrids included some interspecific hybrids. On the other hand, Persson (1974) produced intraspecific hybrids in the *A. maritima* complex, but she was not able to produce any interspecific hybrids.

Controlled hybridization of sagebrush (section *Tridentatae*) is no easy matter. The small perfect flowers are impossible to hand emasculate. Our attempts to induce male sterility by using hot water and the ethelyne analog, Ethrel®, were not successful. The hot water treatment at 40° and 45°C for 2, 5, and 10 minutes stopped all seed development when applied just prior to flower head opening. Higher water temperatures

(30 C) killed the plant tissues. Our experiments at inducing male sterility with Ethrel® failed to uncover any differential action on pollen and ovule formation such as occur on wheat and other grasses (Rowell and Miller 1971). Our experiments with more conventional techniques; namely, mass pollination, were more successful, but the results were not definitive (see table 2, page 28).

The *Tridentatae* do not appear to be self-sterile (table 2). Seed was set in the unopened control bags. We cannot make the case for self-compatibility point as strongly as we would like to, however, because the pollination bags sift small amounts of pollen. The bakery bags sifted no more pollen than commercial paper and woven cloth bags prepared specifically for hybridization experiments. We (McArthur and Blauer, data on file at the Shrub Sciences Laboratory, Provo, Utah) found only minimal amounts of pollen on petroleum-coated microscope slides inside of the control bags. These tests were made primarily with *Atriplex* pollen but also with *Artemisia* pollen and unidentified pollen. Pollen does not sift into the bags in quantity enough to produce seed sets of up to 300 seeds per pollination bag (table 2). Apparently, therefore, selfing occurs.

We believe, above and beyond the background of selfing, hybrid seed is also set. Our 3 years' data (table 2) show a trend for higher interpopulation and intrapopulation seed set than seed set in the control bags (selfing and sifting). The differences are not significant, perhaps because of the wide variations in seed set in the bags. The environment within the bags was not natural. When the bags were opened, some enclosed branches were drier and some more moist than adjoining unbagged branches.

CHARACTERISTICS OF THE GENUS *CHRYSOTHAMNUS* (RABBITBRUSH)

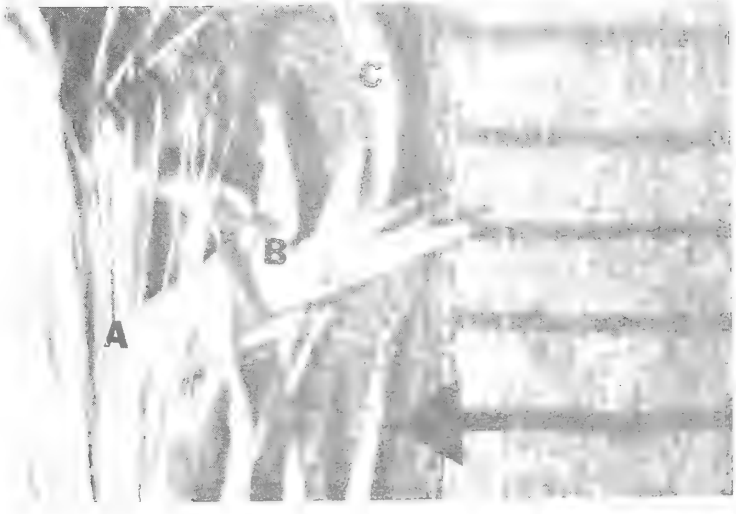
This genus consists of much-branched subshrubs or shrubs up to 3 m high with ascending to erect stems bearing alternate, narrow, deciduous leaves. The herbage ranges from glabrous to densely tomentose and is commonly resinous and aromatic.

Rabbitbrush flowers are borne in heads that in turn are arranged into cymes, racemes, or panicles (fig. 35). The heads usually contain from 5 to 15 yellow or sometimes white disc flowers and are subtended by involucral bracts (fig. 36) arranged into 5 more or less distinct vertical ranks. Each flower contains a pappus of abundant, white, slender capillary bristles (fig. 37), a 5-toothed or cleft tubular to funnelform corolla, 5 stamens united by their anthers around the style, and a pistil with

*Figure 35.--The inflorescence of Howard rabbitbrush (*C. parryi *ssp.* howardi*). Plant growing at Current Creek, Duchesne Co., Utah.*

Figure 36.--Involucral bracts of Chrysothamnus *(12X). (A)* C. nauseosus *ssp.* albicaulis *with acutely angled tips. Specimen from Deeth, Elko Co., Nev. (McArthur and Blauer N-18).*

(B) C. nauseosus *ssp.* salicifolius *with obtusely angled tips. Specimen from Strawberry Valley, Wasatch Co., Utah (Tierman* s.n.*).*



(C) C. parryi *ssp.* attenuatus *with long, attenuate tips (arrow). Specimen from Salina Canyon, Sevier Co., Utah (McArthur and Blauer SC 74-40). Note pappus (a), corrola (b), and stigma (c).*

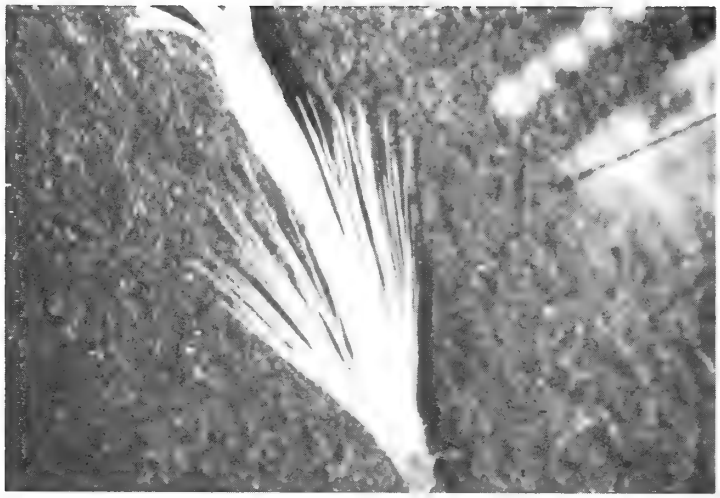


*Figure 37.--Pappus on developing achene of mountain rubber rabbitbrush (*C. nauseosus *ssp.* salicifolius*). Specimen from Ephraim Canyon, Sanpete Co., Utah (7X).*

two exserted stigmas (fig. 38) and an ovary that develops into a 1-seeded glabrous to densely pubescent achene. The basic chromosome number for rabbitbrush is $x = 9$. Polyploidy is limited in the genus, having been found in only a few subspecies of *C. viscidiflorus* (Anderson 1971).

The rabbitbrushes are endemic to western North America in open plains, valleys, foothills, and mountains from sea level to 3,300 meters (10,900 feet) in elevation (Hitchcock and others 1969; USDA Forest Service 1974). In addition to their importance as browse and soil stabilizers, rabbitbrushs are used by the Hopi Indians for making windbreaks, arrows, wickerwork, and as fuel in their ceremonial chambers (kivas). Flowers and inner bark may be used to make yellow and green dye, respectively (Kearney and Peebles 1960). Rabbitbrushes, particularly the larger ones, provide late-season nectar that produces a dark, strong-flavored honey (D. T. Booth, letter 11/16/77). The dark color and late nectar flow (coming after most sources have ceased) make rabbitbrush especially valuable in winter beehives.

Besides the eight species (*C. albidus, C. depressus, C. greenei, C. linifolius, C. nauseosus, C. parryi, C. vaseyi,* and *C. viscidiflorus)* treated in the publication, there are a few other *Chrysothamnus* species. Some, for example, *C. pulchellus* do not occur in

*Figure 38.--Flower head of mountain rubber rabbitbrush (*C. nauseosus *ssp.* salicifolius*. Specimen from Ephraim Canyon, Sanpete Co., Utah (7X).*

the Intermountain area; others, such as *C. paniculatus* and *C. teretifolius*, occur in portions of the Intermountain area but are only minor constituents of the flora.

Chrysothamnus albidus (Jones) Greene (alkali or white flowered rabbitbrush)

Alkali rabbitbrush is a much-branched, leafy shrub. It has erect, brittle, glabrous, very resinous, white-barked branches up to 1 meter high (fig. 39a). The glabrous, filiform leaves are 1.5 to 4 cm long, 0.5 to 2 mm wide, and the margins become revolute. Their surface is covered with small pits and abundant resinous exudate.

Heads with 4 to 6 white disc flowers each are arranged in small compact cymes. Each head is subtended by approximately 15 glabrous, resinous, involucral bracts. These are 7 to 9 mm long and terminate in attenuate to acuminate, usually curved tips. The pappus is abundant and longer than the corollas. Mature achenes are about 4 mm long and densely covered with long soft hairs. Blooming occurs from August to November.

Hybridization.--*Chrysothamnus albidus* has a chromosome number of $2n = 18$ (Anderson 1966, 1971; Anderson and others 1974). Only diploid individuals have been found in this species. Hybridization between this species and at least *C. nauseosus* appears possible. Anderson (1970) has obtained seed from *C. albidus* that produced plants somewhat intermediate between the putative parents.

Perhaps greater alkalinity tolerance could be bred into the more palatable forms of rubber rabbitbrush by crossing them with alkali rabbitbrush. These forms could then be used to increase palatable forage as well as ground cover in sparsely vegetated alkaline areas.

Distribution and habitat.--This species is a definite halophyte. It occurs most commonly along the western side of the Great Salt Lake desert, but is also found across Nevada to eastern central California in alkaline soils. Alkali rabbitbrush may invade strongly alkaline areas as a pioneer plant. In less alkaline flats it may be associated with threadleaf rubber rabbitbrush, giant wildrye, and greasewood. Its type locality is listed as "alkaline soil, Wells, Nevada" (Hall and Clements 1923).

Use.--This species has value as ground cover on alkaline soils.

Chrysothamnus depressus Nutt. (dwarf rabbitbrush)

Dwarf rabbitbrush is a small, irregularly branched, depressed shrub or subshrub 3 dm high or less, with numerous short branches arising from decumbent lower stems (fig. 40). The branches are covered with a dense scabrid pubescence. The narrowly oblanceolate to spatulate leaves are 0.7 to 2 cm long, 1 to 4 mm wide, and finely puberulent or scabrous like the branches.

The heads contain 5 disc flowers and are arranged into compact terminal cymes. Involucral bracts have mucronate to attenuate tips, are 10 to 13 mm long, and are arranged into 5 distinct vertical ranks. Achenes are 5 to 5.5 mm long and glabrous or obscurely pubescent toward their apex. The soft brownish-white pappus is slightly longer than the corolla. Blooming occurs from May to October.

Hybridization.--*Chrysothamnus depressus* has a chromosome number of $2n = 18$ (Anderson 1966). It is not known to hybridize with any other rabbitbrush.

Distribution and habitat.--This species occurs on dry plains, hills, and rocky mountain slopes from 1,000 to 2,100 meters in elevation (3,300 to 6,900 feet) scattered over western Colorado, New Mexico, Utah, Nevada, and southeastern California.

Figure 39.--Drawings of Chrysothamnus *taxa. (A)* C. albidus, *Robertson* s.n., *Wells, Elko Co., Nev. (1.1X). (B)* C. parryi *ssp.* attenuatus, *McArthur and Blauer SC 74-35, Wasatch Pass, Sevier Co., Utah (1.1X). (C)* C. parryi *ssp.* monocephalus, *McArthur and Blauer N-82, Slide Mountain, Washoe Co., Nev. (1.6X).*

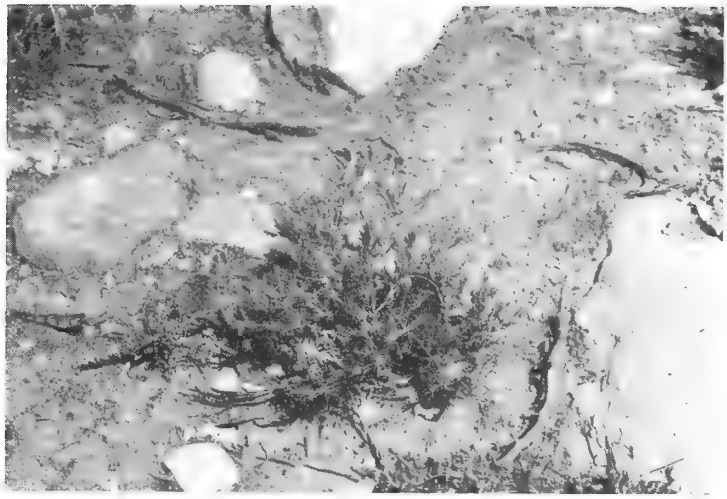


*Figure 40.--Dwarf rabbitbrush (*C. depressus*) growing near the mouth of Ephraim Canyon, Sanpete Co., Utah.*

Use.--Dwarf rabbitbrush is often heavily browsed by sheep, cattle, and wildlife (Hall and Clements 1923). It transplants readily and is useful for stabilizing depleted soils on which it readily grows. It is a source of protein when grasses and broadleaf herbs have dried.

Chrysothamnus greenei (Gray) Greene (Greenes rabbitbrush)

Greenes rabbitbrush is a small highly branched shrub only 1 to 3.5 dm high. Its glabrous brittle twigs are green at first but soon become white and shiny. Bark on the lower branches often peels off in sheets (Hall and Clements 1923). The nearly glabrous or slightly scabrous-ciliate leaves are narrowly linear, 1.2 m or less wide, 1 to 3.5 cm long, and are more or less viscidulous.

Flower heads normally contain 5 disc flowers in rounded or flat-topped cymes. The involucral bracts are 5 to 7 mm long, arranged in 5 poorly defined vertical ranks, and terminate in narrowly acuminate, greenish tips. The tubular to funnelform corollas may be whitish or yellow and 4 to 4.5 mm long. Achenes are about 3 mm long and are covered with dense, long, shaggy hairs.

Greenes rabbitbrush has been divided into 2 subspecies, ssp. *greenei* and ssp. *filifolius* by some authors (Hall and Clements 1923; Harrington 1954; and Kearney and Peebles 1960). These authors separate ssp. *filifolius* from *greenei* by its normally larger stature and shorter narrower leaves. We believe no subspecies should be recognized because the purported subspecies (1) are chromatographically similar (McArthur and others 1978) and (2) often occur in mixed populations. The chromatographic data from McArthur and others (1978) further suggest that *C. greenei* could be considered a subspecies of *C. viscidiflorus* rather than a separate species. *Chrysothamnus greenei* closely resembles *C. viscidiflorus*, particularly ssp. *stenophyllus*. Both have a low, bushy habit, white-barked stems, and short narrow leaves. Furthermore, the *axillaris* form of *stenophyllus* has involucral bracts with attenuate tips (Anderson 1964) that closely resemble those of *C. greenei*. We concur with Hall and Clements (1923) who felt the similarity between *C. greenei* and *C. viscidiflorus* indicated a close genetic relationship.

Hybridization.--*Chrysothamnus greenei* has a chromosome number of $2n = 18$ (Anderson 1966). Anderson (letter 3/30/76) believes *C. viscidiflorus* ssp. *stenophyllus* form *axillaris* "may represent some sort of introgression of *C. greenei* into *C. v. stenophyllus*."

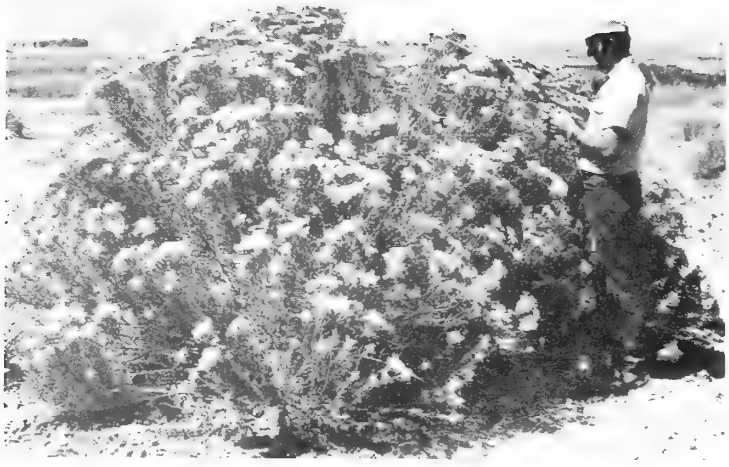


*Figure 41.--A large spreading rabbitbrush (*C. linifolius*) growing at the Snow Field Station.*

Distribution and habitat.--Greenes rabbitbrush occurs on plains, valleys, and foothills in Colorado, New Mexico, Nevada, and Utah. Overgrazing allows it to greatly increase, sometimes forming a subclimax or even climax community (Halls and Clements 1923).

Use.--This species provides cover and browse in areas where it is abundant.

Chrysothamnus linifolius Greene (spreading rabbitbrush)

Spreading rabbitbrush is a tall, robust shrub up to 2.4 meters high (fig. 41). *Chrysothamnus linifolius* spreads underground by lateral roots that form adventitious shoots (fig. 42) (Anderson 1964). In the genus, only *C. parryi* shares the underground spreading trait and then not nearly to the extent *C. linifolius* does. Leaves are large, flat, green, glabrous, lanceolate to oblong-lanceolate, 2 to 5 cm long, and 4 to 8 mm wide.

Heads contain 4 to 6, usually 5 disc flowers and are arranged into broad, loose cymes. The involucral bracts have obtuse tips with thickened green spots similar to those of *C. vaseyi*. These spots, however, dry to a brown color. Achenes are covered

*Figure 42.--Root sprouts, foreground, of spreading rabbitbrush (*C. linifolius*) at the Snow Field Station.*

with dense, long, soft hair. Blooming occurs during August and September. Cleaned seed averages 3,140 per gram (1,425,000 per pound).

Hybridization.--Chrysothamnus linifolius has a chromosome number of $2n = 18$ (Anderson 1966 and 1971). Hall and Clements (1923) reported that intermediates showing all gradations in characteristics between *C. linifolius* and *C. viscidiflorus* ssp. *typicus* (*viscidiflorus*) have been noted in the area around Point of Rocks, Wyoming.

Distribution and habitat.--Spreading rabbitbrush occurs in Wyoming, Colorado, New Mexico, Utah, and Nevada. It is most abundant in alkaline soils along roadcuts, barrow pits, ditches, streams, and washes in the Upper Colorado River drainage.

Use.--The aggressive underground spreading characteristics of the species make it a valuable stabilizer of disturbed alkaline soils (McArthur and others 1974; Plummer 1977).

Chrysothamnus nauseosus (Pallas) Britt. (rubber rabbitbrush)

Rubber rabbitbrush is a shrub usually 3 to 20 dm high, but it varies from dwarf forms to types over 3 m high. Usually, several erect stems arise from the base and these branch to form rounded bushes. Branches are covered with a green, yellow-green, gray-green to white feltlike tomentum usually infiltrated with a resinous gum, making the plant somewhat sticky. This coating is often mistaken for part of the bark but can be discerned by scraping with a knife edge or a fingernail.

Leaves are nearly filiform in some subspecies to broadly linear in others. Leaves vary from 18 to 63 mm long and are covered with a tomentose vestiture. They are not twisted or gland-dotted.

The heads of this species are usually arranged into a cymose inflorescence. Each head bears 20 to 25 glabrous to densely tometose involucral bracts arranged in up to 5 vertical rows (fig. 36a). Rubber rabbitbrush blooms from August to October. Plants at higher elevations bloom earlier than those at lower elevations. Most forms of *C. nauseosus* are among the latest bloomers of the genus. Close examination of the buds and flowers in various stages of development revealed that the anthers open to release pollen during late bud and just as the buds are opening. As the bud continues to open, the anther tube is pushed above the corolla by elongating filaments. At the same time, the styles elongate and push the stigmas up through the anther tube until the stigmas are fully exserted at full bloom. The stigmas then separate to expose their receptive inner surface (fig. 38). By this stage of development, most, if not all, pollen from the anther tube of the same flower has been shed. The later maturing stigmas, particularly from the first flowers to bloom on an individual shrub, indicate that *Chrysothamnus* is predominantly self-fertilized (Anderson 1966) because pollen from later developing flowers in the same head, or from other heads on the same bush, may be transferred to receptive flowers on that bush. This genus is not apomictic (Anderson 1966). Fruits mature in October and November. Cleaned seed averages 1,530 per gram (693,000 per pound) (Plummer and others 1968).

We have recently discovered that galls induced by tephritid flies are differentially distributed among the subspecies of rubber rabbitbrush (McArthur and others 1979). Over much of its range, ssp. *albicaulis* is infested with a persistent round stem gall, 0.3 to 1.2 cm in diameter (fig. 43). In our observations, this gall was restricted to ssp. *albicaulis*. Subspecies *consimilis* and *graveolens*, on the other hand, have a less persistent, fluffy stem gall reminiscent of a ball of cotton about 0.7 to 1.4 cm in diameter (fig. 43). This gall is found also on ssp. *albicaulis* in southern areas (near Kanab, Utah, and Colorado City, Arizona). The round gall is absent in these

Figure 43.--Contrasting tephritid galls on C. nauseosus *subspecies. (A.) Callus gall on ssp.* albicaulis. *(B.) Cotton gall on ssp.* graveolens. *Specimens from Gould's Wash, Washington Co., Utah.*

areas. We are currently studying the absolute specificity of these galls. In areas where these subspecies occur together the galls are very specific. We have observed only a few cases of cross gall inoculation and then only on putative hybrid plants. Wangberg (1976) independently observed some species and subspecies specificity of tephritid galls on *Chrysothamnus* in Idaho. Wangberg (1976) found less specificity for the round gall in Idaho than we did in Utah. He identified the tephritid flies that induce the galls as two different species of *Aciurina*.

Hybridization.--Chrysothamnus nauseosus has a chromosome number of $2n = 18$ (Anderson 1966, 1971; Kovanda 1972; Anderson and others 1974). This rabbitbrush is a highly variable species of numerous ecotypes and biotypes from which a large number of segregates have been described. Most important among these, in the Great Basin at least, are the subspecies: *salicifolius, albicaulis, graveolens,* and *consimilis*. Other less common and less important subspecies include: *junceus, gnaphalodes, hololeucus, leiospermus,* and *turbinaturs*.

L. C. Anderson (letter 4/12/72) advised using *C. nauseosus* in hybridization programs since all the natural *Chrysothamnus* hybrids he had found involved this species. Anderson has found hybrids of *C. nauseosus* ssp. *nauseosus* X *C. parryi* ssp. *parryi*, *C. albidus* X *C. nauseosus*, and *C. nauseosus* ssp. *albicaulis* X *Haplopappus macronema*. The last named combination is the putative parentage of the rare endemic *C. bolanderi* (Anderson and Reveal 1966). In 1966 there were only 25-50 plants of this species--all at Mono Pass, California. In his artificial hybridization attempts, Anderson (letter 4/12/72) inserted pollen between the appressed stigmatic lobes before they separated naturally. This technique produced no hybrids but did block self-pollination in several cases so that the recipient flowers set no seed.

During our field studies of intermixed *albicaulis-consimilis, albicaulis-graveolens,* and *graveolens-consimilis* populations, we consistently found considerable intermixing of color and leaf characteristics, indicating that introgression had occurred. Our work with paper chromatography supports this observation (Hanks and others 1975). We found plants intermediate between *C. nauseosus* ssp. *salicifolius* and *C. parryi* ssp. *nevadensis* and *howardi* in Utah and Nevada, respectively. The subspecies of *C. nauseosus* found in Colorado intergrade to some degree, according to Harrington (1954).

We agree with Hall and Clements (1923) that "improvement in any desired direction may be brought about by selection, or by hybridization, or by both of these methods."

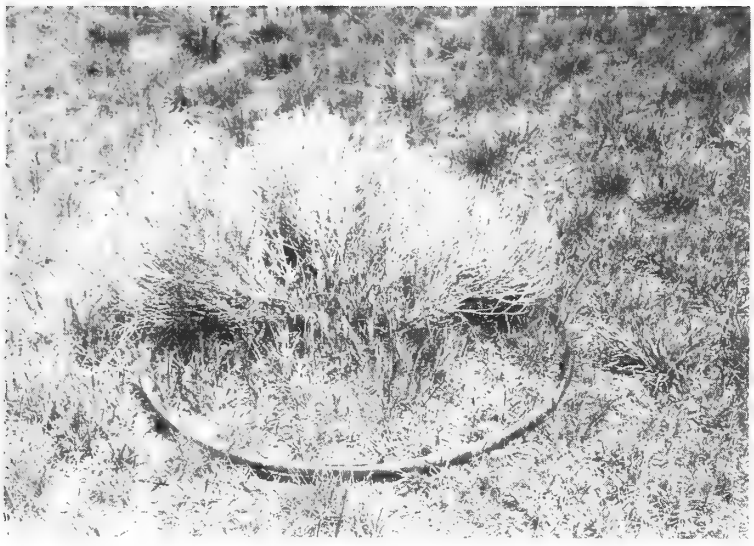


*Figure 44.--White rubber rabbitbrush (*C. nauseosus *ssp.* albicaulis*) in a thick stand of grasses [(intermediate wheatgrass (*Agropyron intermedium*) and crested wheatgrass (*Agropyron cristatum*)] at Pigeon Hollow, Sanpete Co., Utah.*

Distribution and Habitat --Rubber rabbitbrush ranges from British Columbia and Saskatchewan south to western Texas, Baja California, and eastern California. It is a common plant on plains, valleys, and foothills. It grows best in openings within the sagebrush, juniper-pinyon, and ponderosa pine zones in sandy, gravelly, or clay-alkaline soils. This species grows at elevations ranging from 150 to 2,750 meters (500 to 9,000 feet).

Rubber rabbitbrush vigorously invades disturbed sites such as roadcuts and overgrazed rangelands. On ranges where big sagebrush has been destroyed by fire, insects, vehicular traffic, or continued heavy grazing, rabbitbrush increases and often becomes the dominant vegetation (Evans and others 1973). Nevertheless, in most habitats, this species is not overly competitive with herbaceous species and on some sites it does not suppress grass. Production of herbaceous cover and percentage of site covered have been notably greater when rabbitbrush is present than when it is not present (Plummer 1959; Plummer and others 1968) (fig. 44).

Use.--Rubber rabbitbrush is an excellent plant for controlling erosion because of its deep roots, heavy litter, and ability to establish on severe sites (USDA Forest Service 1974). Once established, this species reproduces easily and spreads fast from its light, plumed, wind-disseminated achene. It also grows vigorously when transplanted. When cut and divided the crown readily forms basal sprouts (Hall and Clements 1923).

The value of *C. nauseosus* as browse varies greatly between subspecies and ecotypes. The white to grayish subspecies such as *albicaulis* and *salicifolius* are more palatable to livestock and big game than the green subspecies, *graveolens* and *consimilis* (fig. 45; McArthur and others 1974; Hanks and others 1975). Throughout much of the summer range, game and livestock browse the plant lightly if at all except under unusual conditions. During late summer and fall when rubber rabbitbrush is in bloom, most livestock and game graze the flowers, and occasionally a few leaves and the more tender stems. Rubber rabbitbrush is most heavily browsed on winter ranges (fig. 46). Rubber rabbitbrush was found in 48 percent of the deer stomachs examined on a portion of winter range in Owens Valley, Inyo County, California, although it never amounted to more than 6 percent of the total food ingested (Sampson and Jesperson 1963). Crude protein content ranged from 9 percent during the dormant months to 11.8 percent in the spring after new leaves had formed (Sampson and Jesperson 1963).

Subspecies.--*Chrysothamnus nauseosus* ssp. *albicaulis* (white rubber rabbitbrush) is a shrub from 6 to 20 dm high with erect leafy branches and leaves covered with a

*Figure 45.--Differential deer browsing on subspecies of rubber rabbitbrush on Bald Mountain, Sanpete Co., Utah. The dark plant (lower left) is the threadleaf rubber rabbitbrush (*C. nauseosus *ssp.* consimilis*), whereas the light plant (center) is white rubber rabbitbrush (*C. nauseosus *ssp.* albicaulis*).*

permanent, dense, white to grayish tomentum (fig. 47). The leaves are 2.5 to 4 cm long, 0.5 to 1.5 mm wide or sometimes to 3 mm wide in a few forms (fig. 48a). The strongly keeled, acute involucral bracts (fig. 38a) are white, more or less tomentose, 8 to 10 mm long, and arranged into 5 distinct vertical ranks. The yellow corollas are 8 to 11 mm long and terminate in lobes 1 to 2 mm long. The achenes are densely pubescent. White rubber rabbitbrush is a common and widespread subspecies found in open places in plains and foothills from British Columbia and Montana southward to northwestern Colorado, Utah, Nevada, and eastern California. It is most abundant in the Great Basin area (Hall and Clements 1923). This subspecies is often found intermixed with ssp. *graveolens* on foothill ranges, and with ssp. *consimilis* in valleys and plains (Plummer 1977). The striking white forms have potential use as ornamentals.

Chrysothamnus nauseosus ssp. *consimilis* (threadleaf rubber rabbitbrush) may reach 3 m in height when mature (fig. 49). It has leafy, erect branches covered with a green to yellow-green dense tomentum. The very narrow threadlike (linear-filiform) leaves are less than 1 mm wide and 2.5 to 5 cm long (figs. 48b, 50). They are usually covered with a green to yellow-green tomentum and are somewhat resinous. When crushed, the leaves and twigs emit a strongly disagreeable odor. The involucral bracts are acute,

*Figure 46.--Sheep browsing white rubber rabbitbrush (*C. nauseosus *ssp.* albicaulis*) near Ephraim, Sanpete Co., Utah.*

*Figure 47.--A white rubber rabbitbrush (*C. nauseosus *ssp.* albicaulis*) growing near Fountain Green, Sanpete Co., Utah. The stake is 1.5 m tall.*

glabrous, and keeled and are arranged in fairly distinct vertical rows. The bracts are 6.5 to 8.5 mm long. The corollas are 7 to 9.5 mm long, with glabrous lobes 1 to 2.5 mm long. The achenes are densely pubescent, suggesting that this subspecies may be a connecting link between rubber rabbitbrush and low rabbitbrush.

Chromatograms of threadleaf rubber rabbitbrush were found to be strikingly similar to those of the *C. viscidiflorus* complex (Hanks and others 1975). Subspecies *consimilis* is most common in alkaline valleys and plains of the Great Basin where it is often associated with various saltbushes. In less alkaline areas *consimilis* intermixes with ssp. *albicaulis* and *graveolens*. *Consimilis* also occurs in alkaline soil outside the Great Basin from western Wyoming, Colorado, and New Mexico to northeastern Oregon and eastern California. A large ecotype that occurs principally in the western part of its range was formerly recognized as a separate subspecies, *viridulus*. Another subspecies, *pinifolius*, has also been reduced to synonymy with *consimilis*. Plants formerly referred to as *pinifolius* grow in southern Colorado and New Mexico. Threadleaf rubber rabbitbrush is one of the least palatable of the *C. nauseosus* subspecies. It may therefore have value in revegetating disturbed sites such as roadcuts where attraction of browsing animals is not desired. This subspecies helps control erosion on open alkaline soils by providing ground cover and soil stabilization.

Chrysothamnus nauseosus ssp. *graveolens* (green rubber rabbitbrush) ranges from 6 to 15 dm high when mature (fig. 51). Its leafy, erect branches are yellow-green to green or sometimes gray-green and are covered with a compact tomentum. The linear leaves are 1 to 3 mm wide, 4 to 6 cm long, and only slightly pubescent (fig. 48c). The involucral bracts are 6 to 8 mm long, glabrous at least on their backs, acute, keeled, and arranged in vertical rows. The yellow corollas are 7 to 9 mm long with lobes 0.5 to 1.5 mm long. Achenes are densely pubescent. Green rubber rabbitbrush is widespread and sporadic from North Dakota to Idaho and southward to western Texas, New Mexico, and Arizona. It is most common on well-drained foothills (fig. 52), but also extends up into the mountains and down into valleys and plains where it is often found intermixed with ssp. *consimilis*. Green rubber rabbitbrush is generally less palatable than the white or grey subspecies, *albicaulis* and *salicifolius*. Nevertheless, some forms of this subspecies have been found which are utilized to a moderate degree by livestock and mule deer.

Chrysothamnus nauseosus ssp. *salicifolius* (mountain rubber rabbitbrush) is a shrub from 3 to 20 dm high (fig. 53). Its ascending to erect twigs are very leafy and are

Figure 48.--Drawing of subspecies of Chrysothamnus nauseosus *(A.)* C. nauseosus *ssp.* albicaulis, *McArthur and Blauer N-18, Wells, Elko Co., Nev. (0.8X). (B.)* C. nauseosus *ssp.* consimilis, *McArthur and Blauer N-42, Deeth, Elko Co., Nev. (0.6X). (C.)* C. nauseosus *ssp.* graveolens, *Blauer 291A, Henryville, Garfield Co., Utah (0.5X). (D.)* C. nauseosus *ssp.* salicifolius, *Tierman* s.n., *Strawberry Valley, Wasatch Co., Utah (1.1X).*

*Figure 49.--A threadleaf rubber rabbitbrush (*C. nauseosus *ssp.* consimilis*) growing near Ephraim, Sanpete Co., Utah.*

Figure 50.--Stem, leaves, and inflorescences of threadleaf rubber rabbitbrush on plant near Ephraim, Sanpete Co., Utah.

*Figure 51.--Green rubber rabbitbrush (*C. nauseosus *ssp.* graveolens*) growing at the Snow Field Station.*

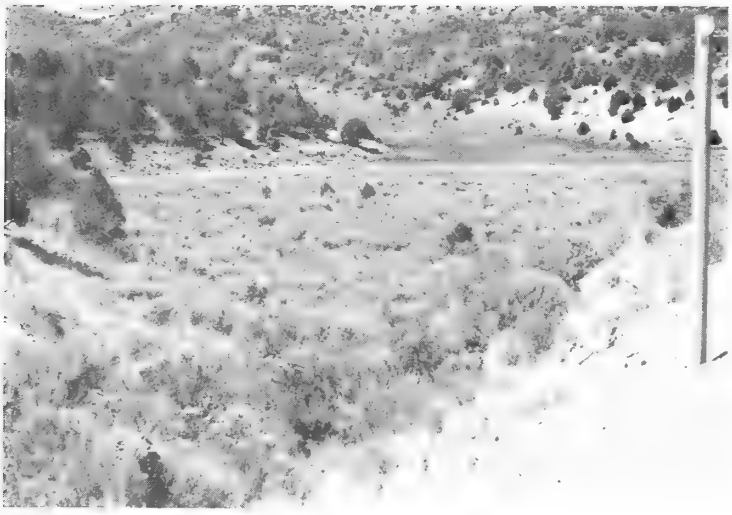


*Figure 52.--Green rubber rabbitbrush (*C. nauseosus *ssp.* graveolens*) growing at Wasatch Pass, Sevier Co., Utah.*

covered with a gray-green, fairly compact tomentum. The leaves are broadly linear, ranging from 4 to 8 cm long and 3 to 10 mm wide, which makes them the largest leaves of the species (fig. 48d). The involucral bracts are 7 to 8 mm long, mostly obtuse, nearly glabrous, and arranged in rather obscure ranks (fig. 36b). The yellow corollas are about 1 cm long and have a minutely pubescent throat. The achenes are densely pubescent. Mountain rubber rabbitbrush was reported by Hall and Clements (1923) to be "apparently rare and confined to Utah." However, we have found it to be fairly widespread at higher elevations in Utah and parts of Nevada (East Humboldt Range, Elko County; and Mt. Charleston, Clark County) as part of the lower subalpine vegetation (fig. 54). L. C. Anderson (letter 3/30/76) considered our Nevada specimens to be ssp. *albicaulis*. So far as we can determine, these specimens do not differ in any important respects from ssp. *salicifolius* growing at its type location (Strawberry Valley, Wasatch County, Utah). It extends down to the foothills in parts of its range where it may be found intermixed with ssp. *albicaulis* and *graveolens* (Plummer 1977). Mountain rubber rabbitbrush appears to be the most palatable subspecies of the four common subspecies, *salicifolius*, *albicaulis*, *graveolens*, and *consimilis* in Utah (Plummer 1977).

Other less common subspecies which, however, have locally large populations include *junceus*, *hololeucus*, and *leiospermus*. Subspecies *junceus* is a nearly leafless,

*Figure 53.--Mountain rubber rabbitbrush (*C. nauseosus *ssp.* salicifolius*) growing at the Snow Field Station.*

*Figure 54.--Mountain rubber rabbitbrush (*C. nauseosus *ssp.* salicifolius*) growing on Strawberry Ridge on the Utah-Wasatch Co. line, Utah.*

yellow-green form adapted to sandy areas in the Colorado River drainage. Subspecies *hololeucus* is a Great Basin foothill and valley form similar to ssp. *albicaulis*. It differs from the latter subspecies only in cryptic floral and achene characteristics. Subspecies *leiospermus* is a low shrub usually less than a meter in height. It has affinities to ssp. *consimilis*. It occurs mostly on arid sites in the southern part of the Great Basin. A distinguishing feature of ssp. *leiospermus* is its glabrous or nearly glabrous achenes.

A few additional subspecies occur principally outside of the Intermountain area. These include *nauseosus* (mostly on the western edge of the northern Great Plains), *mohavensis* (southern California), and *turbinatus* (Colorado plateau).

Chrysothamnus parryi (Gray) Greene (parry rabbitbrush)

Parry rabbitbrush is a shrubby species somewhat intermediate in height, stem and leaf tomentum, and growth habit between rubber rabbitbrush and low rabbitbrush. Parry rabbitbrush is a low, dense shrub similar in habit to certain forms of *C. viscidiflorus*. It is usually from 2 to 6 dm in height with numerous spreading to erect flexible branches (fig. 55). Like *C. nauseosus*, the branches of Parry rabbitbrush are covered

*Figure 55.--Howard rabbitbrush (*C. parryi *ssp.* howardi*) growing at Current Creek, Duchesne Co., Utah.*

with a feltlike white to green tomentum. The tomentum, however, is neither as dense nor resinous as in rubber rabbitbrush. Paulsen and Miller (1968) observed that Parry rabbitbrush spread from underground roots. We have recently confirmed this phenomenon in ssp. *attenuatus*.

The glabrous to tomentulose, somewhat viscid leaves are narrowly linear to elliptic, and range in size from 0.5 to 8 mm wide and 1 to 8 cm long.

Flower heads usually are arranged in terminal leafy racemes (fig. 35) that sometimes form panicles. The involucral bracts are 9 to 14 mm high and terminate in acuminate to very attenuate herbaceous tips (fig. 36c). The yellow, tubular to funnelform corollas are 8 to 11 mm long. Achenes are 5 to 6 mm long and are covered with long, shaggy, appressed hairs. Blooming occurs from July to September. Cleaned seeds average 550 per gram (250,000 per pound).

Hybridization.--*Chrysothamnus parryi* has $2n = 18$ chromosomes (Anderson 1966, 1969, 1971). This species is composed of 10 subspecies, 6 of which occur in the Intermountain region (Hall and Clements 1923). Among the *Chrysothamnii*, *Chrysothamnus parryi* is probably most closely related to *C. nauseosus* with which it shares similarities in pubescence, corolla, shape, and style-branches. In our fieldwork through Utah and Nevada, we have found plants intermediate between *C. nauseosus* ssp. *salicifolius* and *C. parryi*. Within the species, intermediate forms are known to occur between ssp. *parryi* and *howardi* and between *howardi* and *attenuatus* (Hall and Clements 1923).

Distribution and habitat.--Parry rabbitbrush occurs in dry, open places in mountains and foothills of western North America from Wyoming and western Nebraska west to California and south to New Mexico and Arizona. Like other species of rabbitbrush, this species tends to increase on overgrazed and disturbed areas.

Use.--Although this species is generally palatable, it is not as widespread or abundant as rubber rabbitbrush and low rabbitbrush and thus not as important for forage. It is browsed mainly during periods of drought, particularly the more abundant subspecies of *attenuatus*, *howardi*, and *parryi*. Parry rabbitbrush has potential value for stabilizing disturbed soils. We have observed several of its subspecies on roadcuts and fills.

Subspecies.--*Chrysothamnus parryi* ssp. *asper* is a low shrub 1.5 dm or more high with slightly spreading to erect branches. Its green leaves, roughened with short-stalked resin glands, are 2 to 5 cm long and 1 to 3 mm wide. The heads contain 5 to 10 disc flowers and are subtended by somewhat ranked involucral bracts with straight tips. This subspecies occurs on mountainsides bordering desert areas from 2,100 to 2,600 meters (6,900 to 8,500 feet) in elevation in western Nevada and eastern California. Its type locality is listed as "Hockett trail, in the valley of Little Cottonwood Creek, eastern slope of the Sierra Nevada of Inyo Co., Cal." (Hall and Clements 1923).

Chrysothamnus parryi ssp. *attenuatus* consists of low shrubs with mostly erect stems up to 6 dm high. It has green, slightly viscid, narrowly linear leaves, 2 to 4 mm long and about 1 mm wide (fig. 39b). The leaves are erect but are not larger than the inflorescence. Heads contain 5 to 7 disc flowers and are subtended by involucral bracts with slender, straight tips. The bracts are ranked into 5 vertical rows. Blooming occurs from August to October. Subspecies *attenuatus* is found in the sagebrush, pinyon-juniper, and yellow pine vegetational types from southern Idaho to Nebraska and south to New Mexico, Arizona, and California. Its type locality is listed as "Marysvale, Utah, at 2,150 m in clay" (Hall and Clements 1923). We recently noted that this subspecies will spread by adventitious shoots from underground roots.

Chrysothamnus parryi ssp. *howardi* (Howard rabbitbrush) is a low shrub (fig. 35). Its spreading basal stems and erect branches are up to 6 dm high (fig. 55). The narrowly linear, tomentose leaves are 2 to 4 cm long, about 1 mm wide, and the upper ones

usually extend beyond the uppermost heads of the inflorescence. Flower heads contain 5 to 7 pale yellow disc flowers. The heads are subtended by vertically ranked involucral bracts usually with spreading tips. Blooming occurs from July to September. This subspecies occurs on dry hills and mesas associated with sagebrush, pinyon-juniper, and yellow pine vegetational types in Utah, western Wyoming, Colorado, New Mexico, and Nebraska. Type locality is listed as "gravelly hills near 'Hot Springs' of Middle Park, Colo." (Hall and Clements 1923).

Chrysothamnus parryi ssp. *monocephalus* is a low shrub from 0.5 to 3 dm high with rigid, spreading branches. Its viscid, somewhat tomentulose leaves are linear-oblanceolate or spatulate, 1 to 3 cm long, and 1.5 cm or less wide (fig. 39c). The upper leaves usually extend beyond the inflorescence. The flowering heads occur singly or in pairs on the end of short leafy branches. The heads contain 5 or 6 disc flowers and are subtended by obscurely ranked involucral bracts with straight, attenuate tips. This subspecies occurs in the high mountains of western Nevada and eastern California on dry rocky slopes between 3,000 to 3,400 meters (9,800 to 11,200 feet). Its type locality is listed as "summit of Mount Rose, Washoe, Co., Nev." (Hall and Clements 1923).

Chrysothamnus parryi ssp. *nevadensis* (Nevada rabbitbrush) consists of low shrubs with ascending to erect branches up to 6 dm high. The linear to linear-oblanceolate leaves are 1.5 to 4 cm long, 0.5 to 3 mm wide, and sometimes green to resinous, but usually gray-tomentose. The uppermost leaves rarely extend beyond the inflorescence. The flowering heads contain 4 to 6 yellow disc flowers and are subtended by ranked involucral bracts with slender recurved tips. *Chrysothamnus parryi* ssp. *nevadensis* occurs between 1,300 and 2,700 meters (4,300 and 8,900 feet) in elevation on dry mountain sides from eastern California to eastern Nevada, southwestern Utah, and northern Arizona. It is most common along the eastern flank of the Sierra Nevada. Type locality is Mount Davidson, Nevada (Hall and Clements 1923).

Chrysothamnus parryi ssp. *parryi* (Parry rabbitbrush) consists of low shrubs with erect branches 3 dm or more high. The uppermost leaves usually extend beyond the inflorescence. Flowering heads contain 10 to 20 disc flowers and are subtended by obscurely ranked involucral bracts with straight attenuate tips. Blooms occur during August and September. Subspecies *parryi* grows in dry plains, valleys, and hillsides in northeastern Nevada, Utah, Wyoming, and Colorado. Type locality is listed as "Rocky Mountains, latitude 39° to 41°" (Hall and Clements 1923).

There are a few other subspecies of *C. parryi* such as *imulus* and *vulcanicus*. These occur outside of or only on the fringe of the Intermountain area and in small numbers (Hall and Clements 1923).

Chrysothamnus vaseyi (Gray) Greene (Vasey rabbitbrush)

Vasey rabbitbrush is a low, rounded shrub with ascending to erect branches up to 3 dm high. The bark on the young branches is pale green to whitish and glabrous, becoming brown and fibrous with age. Leaves are linear to linear-oblanceolate, 1 to 2.5 cm long, 1 to 3 mm wide, and glabrous.

Heads contain 5 to 7 disc flowers each and are arranged into small, compact cymes. The obscurely ranked involucral bracts are 5 to 7 mm high, oblong, obtuse to rounded, and all but the innermost have a thickened greenish spot near the apex. The achenes are about 5 mm long, terete, longitudinally 10-striate, and glabrous. Blooming occurs from July to September.

Hybridization.--This species has a chromosome number of $2n = 18$ (Anderson 1966). The populations of *C. vaseyi* seem fairly stable with little variation (Hall and Clements 1923).

Distribution and Habitat.--*Chrysothamnus vaseyi* occurs scattered over plains, hillsides, and mountain valleys at altitudes of 1,700 to 2,600 meters (5,600 to 8,500 feet) in Utah, Wyoming, Colorado, New Mexico, and Arizona (Hall and Clements 1923).

Use.--This shrub is probably browsed by sheep, but is small and so scattered it is of little value.

Chrysothamnus Viscidiflorus (Hook.) Nutt. (low rabbitbrush[7])

Low rabbitbrush varies in appearance and foliage characteristics. It is usually 3 dm to 1 m tall with many erect stems branching from a simple base. The brittle, erect twigs are glabrous or puberulent with pale green or white bark.

Leaves are narrowly linear to oblong or lanceolate, 1 to 6 cm long and often twisted. Leaf vestiture is glabrous or pubescent and commonly viscidulous with usually scabrous margins. Degree of pubescence may vary tremendously in variants of this species. As Hall and Clements (1923) pointed out, sometimes the pubescence among the subspecies of *viscidiflorus* "will occur as a fairly dense though minute puberulence in certain plants, while others almost exactly duplicating these in every other respect will be perfectly glabrous." Furthermore, L. C. Anderson (letter 3/30/76) has observed good correlation between plant stature and leaf size of ssp. *viscidiflorus* and *lanceolatus* with altitude and amount of precipitation.

Flower heads containing approximately 5 perfect, fertile disc flowers each are arranged in compact terminal cymes. Involucral bracts number about 15 per head and are arranged in poorly to well defined vertical ranks. The bracts of some subspecies have a greenish or brownish thickened spot near their apex. Low rabbitbrush averages about 1,725 cleaned seeds per gram (782,000 per pound) (Plummer and others 1968).

Hybridization.--*Chrysothamnus viscidiflorus* is the center of a polyploid species complex with a basic chromosome number of $x = 9$. Diploid ($2n = 18$), triploid ($2n = 27$), tetraploid ($2n = 36$), pentaploid ($2n = 45$), and hexaploid ($2n = 54$) populations of this species are known to occur (Anderson 1966, 1971; Anderson and others 1974).

This species includes numerous subspecies and ecotypes within subspecies. Most important among these in the Great Basin are 2 glabrous subspecies, *viscidiflorus* and *stenophyllus*, and 2 pubescent subspecies, *lanceolatus* and *puberulus* (fig. 56). Hall and Clements (1923) believe numerous intergrades have been held together in one rather close species through interbreeding where their ranges meet or overlap. Abrams and Ferris (1960) describe *C. viscidiflorus* as a highly polymorphic species composed of several freely intergrading subspecies of overlapping distribution. We invariably find intermediates when doing fieldwork on this species. We believe forms of low rabbitbrush may be improved for grazing and other uses through selection and breeding. Because each subspecies is self-fertile and predominately self-pollinated, each maintains its identity despite occasional outcrossing (McArthur and others 1978).

Distribution and habitat.--Low rabbitbrush is one of the most widely distributed shrubs on rangelands throughout western North America. It occurs in dry, open areas from British Columbia and North Dakota, south to New Mexico, Arizona, and eastern California at elevations between 790 and 3,350 meters (2,600 and 11,000 feet). Low rabbitbrush is usually associated with sagebrush, snakeweed (*Xanthocephalum*), and other species of rabbitbrush.

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[7]Other common names include yellowbrush, yellow rabbitbrush, yellowsage, rabbitsage, sticky-leaved rabbitbrush, and Douglas rabbitbrush.

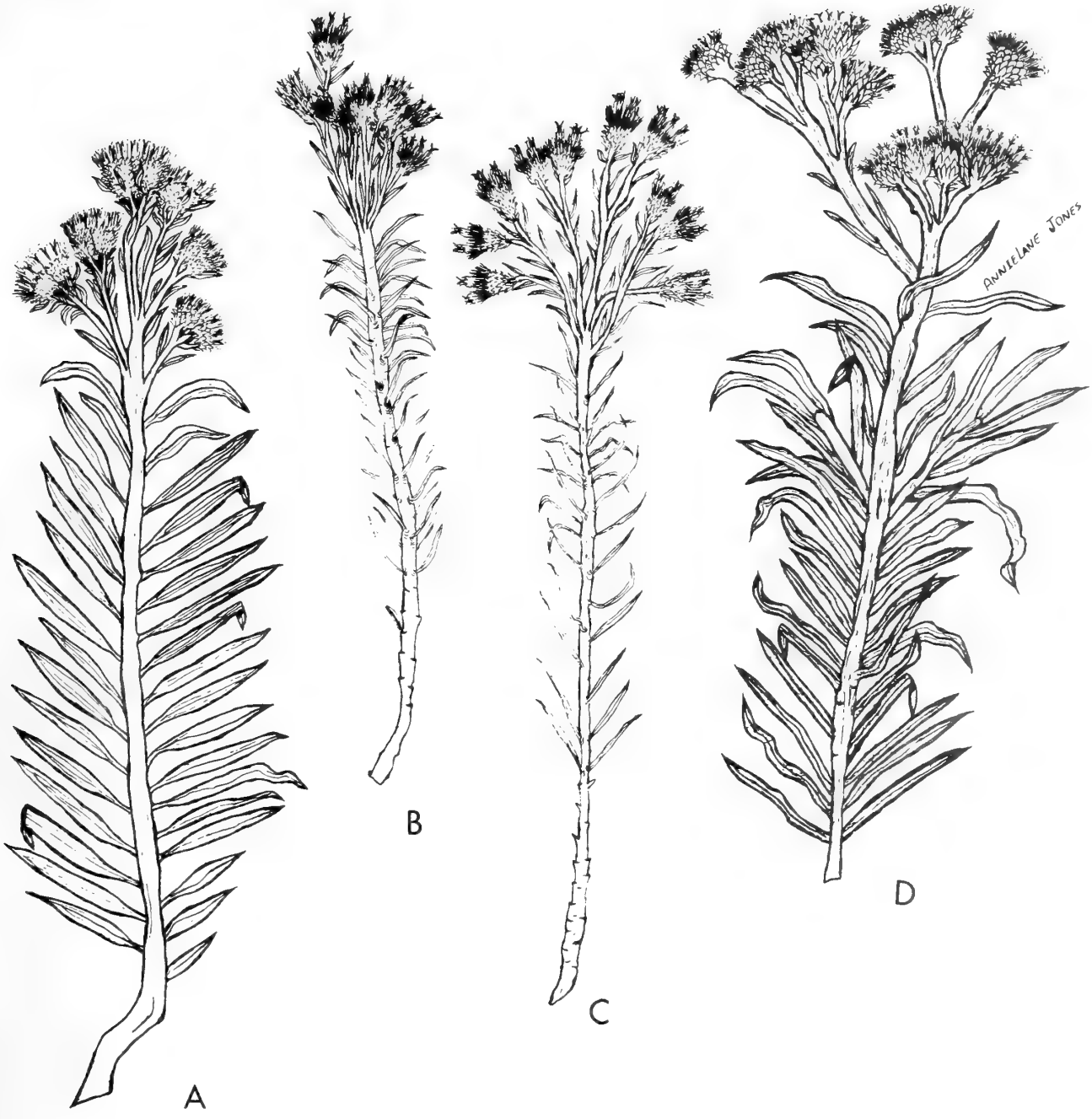

Figure 56.--Subspecies of Chrysothamnus viscidiflorus. *(A.)* C. viscidiflorus *ssp.* lanceolatus, *McArthur and Blauer EC74-32, Wasatch Plateau, Sanpete Co., Utah (1.0X). (B.)* C. viscidiflorus *ssp.* puberulus, *McArthur and Blauer EC74-1, mouth of Ephraim Canyon, Sanpete Co., Utah (0.9X). (C.)* C. viscidiflorus *ssp.* stenophyllus, *McArthur and Blauer N-159, Caliente, Lincoln Co., Nev. (1.1X). (D.)* C. viscidiflorus *ssp.* viscidiflorus, *McArthur and Blauer SC74-7, Salina Canyon, Sevier Co., Utah (1.1X).*

Use.--This shrub may provide an important supply of browse to both game and livestock, particularly during late fall and winter after more desirable forage has been utilized. Throughout the Great Basin, low rabbitbrush, especially the flowering shoots, provides good sheep feed. In California small amounts of low rabbitbrush were found in 10 to 14.8 percent of a large number of deer stomachs examined between October and January (Sampson and Jespersen 1963). There is much variation in palatability among the different subspecies. Some may be heavily utilized, whereas others are utilized little if at all (McArthur and others 1974). Subspecies *stenophyllus* on rocky foothills is often heavily used and sometimes destructively so, with animals preferring mature or partially mature plants to green immature ones. On a Utah winter range, this subspecies averaged up to 11.31 percent by weight of the diet of sheep (Cook and Harris 1950; Cook and others 1954). We have observed substantial use on ssp. *lanceolatus* in widely scattered areas of Utah and Nevada.

Antelope, elk, and bighorn sheep, as well as deer and livestock, show varying preferences for low rabbitbrush, depending on season, locality, and subspecies.

This species, like rubber rabbitbrush, increases rapidly and vigorously on overgrazed or otherwise disturbed sites. Some subspecies such as stickyleaf low rabbitbrush (ssp. *viscidiflorus*) and mountain low rabbitbrush (ssp. *lanceolatus*) adapt well to higher elevations while other subspecies such as narrow-leaf low rabbitbrush (ssp. *stenophyllus*) and hairy low rabbitbrush (ssp. *puberulus*) do best in lower desert and foothill habitats (Plummer 1977). Low rabbitbrush is valuable for revegetating depleted rangelands and other disturbed sites, such as strip mines and roadsides.

Subspecies.--*Chrysothamnus viscidiflorus* ssp. *lanceolatus* (mountain low rabbitbrush) is a small shrub from 2 to 5 dm tall (figs. 56a, 57). Its branches are straw-colored or gray and are finely pubescent. Flower heads are borne in small compact cymes with densely pubescent branches. Involucral bracts are 5 to 6.5 mm long, lanceolate to oblong, obtuse, and glabrous to pubescent. Achenes are densely strigose. On the basis of his systematic investigations in the genus *Chrysothamnus*, L. C. Anderson (letter dated 5/17/76) recommended placing the former ssp. *elegans* in synonomy with *C. viscidiflorus* ssp. *lanceolatus*. Our chromatographic work (McArthur and others 1978) supports this consolidation. Specimens we collected as *elegans* could easily be placed in ssp. *lanceolatus* or *puberulus*, depending on leaf width characteristics. Mountain low rabbitbrush is widespread and fairly common in dry foothill and mountainous habitats from 1,520 to 3,200 meters (5,000 to 10,500 feet) ranging from British Columbia, east to Montana, and south to New Mexico, Utah, and Nevada. This subspecies may be found

*Figure 57.--Mountain low rabbitbrush (*C. viscidiflorus *ssp.* lanceolatus*) growing at the Snow Field Station.*

growing with such shrubs as big sagebrush, snakeweed, various subspecies of rubber rabbitbrush (ssp. *salicifolius*, *albicaulis*, and *graveolens*), other subspecies of low rabbitbrush (*stenophyllus*, *viscidiflorus*, and *puberulus*), Greenes rabbitbrush (*C. greenei*), and Parry rabbitbrush (*C. parryi*).

Chrysothamnus viscidiflorus ssp. *puberulus* (hairy low rabbitbrush) is a small shrub up to 5 dm high with yellowish to green, finely pubescent branches (fig. 58). Its linear-filiform to linear leaves are sparsely to densely pubescent with scabrid-ciliate margins, and are usually twisted or revolute. The leaves are up to 2 mm wide and up to 3 cm long (fig. 56b). Flower heads are borne in small compact cymes with densely pubescent branches. Involucral bracts are about 5 to 6 mm long, lanceolate to oblong, acute to obtuse, and are usually marked with a thickened greenish spot near their tips. Hairy low rabbitbrush occurs on dry plains, valleys, and foothills, especially on poorer soils and disturbed areas. Its range extends from British Columbia to Montana northward to New Mexico, Arizona, Nevada, and eastern California. This subspecies is most abundant in the big sagebrush communities of western Utah, Nevada, and southern Idaho. However, it has been found growing in one locality or another with most of the other subspecies of low rabbitbrush, shadscale, winterfat, halogeton (*Halogeton glomeratus*), and occasionally with pinyon and juniper.

Chrysothamnus viscidiflorus ssp. *stenophyllus* (narrowleaf low rabbitbrush) is a low, glabrous shrub up to 3 dm high with white bark. Leaves are linear-filiform, often twisted, viscidulous, 1 mm or less wide, 1 to 3 cm long, and glabrous except for the usually scabrid and revolute margins (fig. 56c). The branches of the small, compact cymes are glabrous. Involucral bracts are 4 to 6 cm long, not keeled, and lance-oblong. Narrowleaf low rabbitbrush is rather common on most desert ranges, particularly in the southern portion of the Great Basin where it sometimes composes more than a third of the vegetative cover (Cook and others 1954). On these ranges this subspecies is usually found in the sagebrush type on poorer soils and disturbed sites, but is also found growing with halophytes such as shadscale, fourwing saltbush (*Atriplex canescens*), greasewood, and halogeton. The species has special usefulness for providing cover on disturbed ranges in arid climates.

Chrysothamnus viscidiflorus ssp. *viscidiflorus* (stickyleaf low rabbitbrush) is the largest subspecies of low rabbitbrush. Mature shrubs are usually more than 5 dm tall, whereas the other subspecies are normally all under 5 dm. Its branches, leaves, and

*Figure 58.--Broom snakeweed (*X. sarothrae*) (right) growing next to hairy low rabbitbrush (*C. viscidiflorus *ssp.* puberulus*) near Ephraim, Sanpete Co., Utah.*

inflorescences are glabrous but viscid (sticky). The broadly linear to narrowly lanceolate, bright green leaves are 1 to 5 mm wide, 2 to 5 cm long, and flat or twisted (fig. 56d). Leaf margins are sometimes scabrid. Crushed foliage usually emits a very pungent odor. Branches of the cymes are glabrous. Involucral bracts are obtuse, oblong, not keeled, and 5 to 7 mm long. Stickyleaf low rabbitbrush is widely distributed on dry plains and hills from Washington, Idaho, and Montana south to Colorado, Utah, Nevada, and eastern California. It occurs primarily in sagebrush and pinyon-juniper communities at elevations between 1,520 and 2,600 meters (5,000 and 8,500 feet). This subspecies often becomes dominant in cleared or overgrazed areas. At lower elevations stickyleaf low rabbitbrush may be found associated with such halophytes as shadscale, winterfat, and halogeton. Other subspecies of low rabbitbrush are also often associated with it. Anderson (1971) recommends placing the former ssp. *pumilus* in synonymy with *C. viscidiflorus* ssp. *viscidiflorus* because its specimens are "only environmentally modified variants of *C. v.* ssp. *viscidiflorus*." Our chromatographic work (McArthur and others 1978) supports Anderson's reduction of *pumilus* to synonomy.

Because of its wide distribution from moist to arid sites, the species is well suited to a wide range of disturbed sites over the western States.

CHARACTERISTICS OF THE GENUS *TETRADYMIA* (HORSEBRUSH)

The genus *Tetradymia* consists of rather low, stiffly branched shrubs. The stems are uniformly canescent or have glabrous to woolly streaks running down the stem internodes from the primary leaves. The tomentum may be permanent or deciduous on both the stem and leaves. Spines may be present.

Tetradymia bears primary and secondary leaves. Primary leaves develop alternately along elongated shoots and are usually long-lived. These leaves are linear to spatulate and may form slender, straight, or recurved spines. Secondary leaves develop in fascicles in the axils of the primary leaves (fig. 59). They are generally short-lived and often dry up and fall away within a few weeks (Strother 1974).

Horsebrush flowers are borne in heads located singly or in pairs in the upper primary leaf or spine axils or are clustered in short, dense racemes or corymbs at the

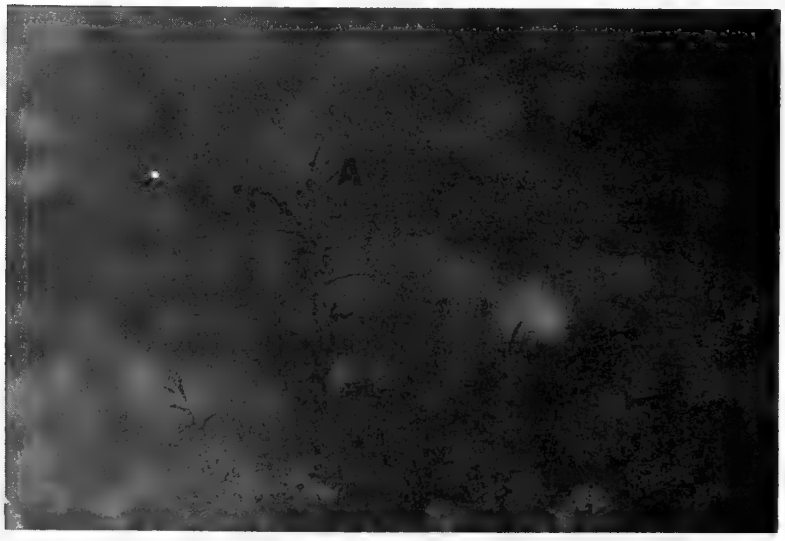

Figure 59.--Primary (A) and secondary (B) leaves on Nuttall horsebrush (T. nuttallii). Specimen growing in Antelope Valley, Sanpete Co., Utah.

tips of branches. Each head contains from 4 to 9 yellow disc flowers. Ray flowers are lacking. Four to 6 equal involucral bracts with overlapping sides subtend each head. The pappus consists of numerous bristles or scales or may be lacking. The ovary of each flower develops into a glabrous to densely long-haired achene.

This genus blooms from April to August depending on elevation, climatic conditions, and species. Numerous small moths, bees, flies, and beetles visit the flowers. Although numerous potential pollinators are available and the flowers are highly fertile, seedlings are not commonly seen in nature. This is probably due to the harsh environment in which *Tetradymia* is usually found (Strother 1974). However, we recently observed many young plants growing in a burned-over area near Wallsburg, Wasatch Co., Utah.

The basic chromosome number for horsebrush is $x = 30$, and sporadically in some species, $x = 31$. Polyploidy occurs in the genus but has only been found in some spineless species (*T. filifolia, T. canescens, T. glabrata*). Strother (1974) found no correlation between either geography or elevation of populations and their chromosome number. He only rarely found variation of chromosome numbers within colonies.

Horsebrush provides some critically needed ground cover in the dry, sparsely vegetated desert ranges where it grows. Although several species are poisonous to sheep and have caused losses of thousands of animals in Utah and Nevada, horsebrush is browsed particularly heavily during winter and early spring on desert ranges and overgrazed areas where little else may be available this time of year. Most severe losses have occurred when hungry animals have been trailed from winter to summer ranges through stands of horsebrush without allowing the animals a chance to graze other plants (Kingsbury 1964). Considerable variation in toxicity within and between species of *Tetradymia* has been noted (Johnson 1974a, 1974b). Hopefully, through careful selection and study, palatable atoxic forms may be discovered and developed.

Four horsebrush species (*T. canescens*, *T. glabrata*, *T. nuttallii*, and *T. spinosa*) are quite common in the Intermountain area. *T. axillaris*, a spiny species, occurs on the edge of the Intermountain area in scattered populations from southwestern Utah to southern California. Two other species are found southwest of the Intermountain area: *T. argyraea* (southeastern California), and *T. comosa* (southern California and Baja California) (Strother 1974).

Tetradymia canescens DC. (Gray horsebrush[8])

Gray horsebrush is a spineless, much branched shrub up to 8 dm high (fig. 60). The branches are covered with a thick tomentum interrupted by glabrous to woolly streaks running down the stem internodes from the base of the primary leaves.

The primary leaves are linear-lanceolate to spatulate, 1 to 3 cm long, 2 to 4 mm wide, and are covered with a gray canescent to tomentose vestiture. The secondary leaves are shorter and narrower than the primary leaves, but are otherwise similar to them.

Flower heads are borne on the tips of numerous short branches in corymb-like clusters. Each head contains 4 light yellow to cream disc flowers. Four lanceolate or ovate to oblong, canescent, involucral bracts subtend each head. The achenes are 3 to 4 mm long and may be glabrous or hairy. The hairs when present are shorter than the abundant, well-developed pappus of bristles.

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[8]Other common names include spineless horsebrush and black sage.

Figure 60.--Gray horsebrush (T. canescens) *growing at Wahsatch Station, Summit Co., Utah.*

This species begins flowering about mid-June in the northern part of its range (southern British Columbia and northeastern Washington) and progresses southward to San Bernardino County, California, and northern Arizona where it blooms in late July or early August (Strother 1974). Cleaned seed average 305 per gram (140,000 per pound).

Hybridization.--Gray horsebrush is a polyploid species with some aneuploidy at the diploid level. Sporadically, specimens with $2n = 62$ chromosomes are found in diploid populations ($2n = 60$). Triploid ($2n = 90$) and tetraploid ($2n = 120$) numbers are also known. Both diploid and triploid colonies are located throughout much of the range of *T. canescens* (Strother 1974).

Suggested hybrids between *T. canescens* and *T. glabrata* have been found in southern Idaho where the flowering period of these two species overlap (Strother 1974). A form with shorter and broader leaves, called *T. inermis*, occurs in Colorado, and plants intermediate between this form and the normal *T. canescens* are as common as the extremes (Harrington 1954).

Distribution and habitat.--The type locality for gray horsebrush is reported to be the Columbia River (Abram and Ferris 1960). It is widespread, however, throughout the Great Basin and adjacent areas, on dry plains, hills, and ridges from southern British Columbia, Montana, Idaho, and Washington southward to New Mexico, Arizona, and California between elevations of 400 and 3,300 meters (1,300 and 10,800 feet). Throughout its range it is associated with the sagebrush, pinyon-juniper, and yellow pine vegetation types (Strother 1974).

Use.--This species is generally regarded to be low in palatability to most animals and may be poisonous if large quantities are consumed. Nevertheless, buds and young leaves are frequently browsed during spring and fall months by sheep, goats, antelope, and deer. Cattle graze *T. canescens* fairly heavily in some areas in Nevada. This shrub probably has merit for establishing cover on severely depleted soils, such as mine spoils.

Tetradymia glabrata Torr. & Gray (littleleaf horsebrush)

Little-leaf horsebrush is a compact, heavily branched shrub up to 12 dm high. The vestiture of its young stems resembles that of gray horsebrush by having glabrous to slightly floccose streaks along the internodes below the primary leaves. These streaks interrupt the otherwise feltlike tomentum.

The primary leaves are more or less appressed, linear-subulate, 0.5 to 1 cm long, and terminate in mucronate or spinose tips. Their vestiture is glabrate to sparsely floccose. The secondary leaves are linear-filiform to slightly clavate, 3 to 10 mm long, and glabrous. They terminate in blunt tips.

Flower heads are arranged in compact, corymb-like clusters terminating the branches. Four glabrous or canescent, lanceolate to obovate, involucral bracts subtend each head which contains four golden yellow to cream disc flowers. Slender, densely hairy achenes, 3 to 4 mm long, are produced. The achene hairs overlap and blend with the bristly pappus, but do not obscure it.

The flowering pattern of this species is just the opposite of gray horsebrush. Little-leaf horsebrush begins flowering first during late April in the southern part of its range in the Mohave Desert and progresses northward to Idaho where it flowers in mid-June (Strother 1974). Seeds on the average are slightly larger than those of *T. canescens*.

Hybridization.--Tetradymia glabrata resembles *T. canescens* in being a polyploid species. Populations of this species with diploid ($2n = 60$) and hexaploid ($2n = 180$) numbers have been found. Sporadic aneuploid-diploid ($2n = 62$) individuals occur (Strother 1974).

Distribution and habitat.--Little-leaf horsebrush is most abundant in the sagebrush desert of the Great Basin but is found scattered in dry open places in foothills associated with sagebrush, creosote (*Larrea tridentata*), Joshua trees (*Yucca brevifolia*), and pinyon and juniper trees from eastern Oregon and western Idaho southward to northeastern California, Nevada, and Utah between 800 and 2,400 meters (2,600 and 8,000 feet). Its type locality is reported as the Sierra Nevada (Abrams and Ferris 1960).

Use.--Tetradymia glabrata is not ordinarily palatable to livestock. However, on overgrazed, depleted rangelands where more desirable browse is not available, this plant may be consumed. If large enough quantities are eaten in the spring when plants are most toxic, poisoning may result.

Johnson (1974a) reported an extremely variable hepatotoxic response of sheep to *T. glabrata* and found that plants in the same stage of development from different localities varied in their toxicity. This variation should allow use of less toxic, more palatable forms that may have potential use in revegetation of the harsh, arid sites where *Tetradymia* grows. Johnson (1974b) stated that prior consumption of *Artemisia* species (*A. nova* and *A. tridentata*) might be necessary for expression of toxic effects of *T. glabrata* (bighead/photosensitization).

Tetradymia nuttallii Torr. & Gray (Nuttall horsebrush)

This species is a rigidly branched, spiny shrub to 12 dm high. Its young stems are woolly-canescent with glabrescent streaks along the internodes below the spines (primary leaves). The stems become glabrate in age.

The primary leaves transform into straight or recurved spines 0.5 to 2.5 cm long (fig. 61). The sparsely tomentose to nearly glabrous spatulate, secondary leaves are 1 to 2 cm long and are borne in fascicles in the axils of the spines.

Heads containing 4 bright yellow disc flowers each are arranged into terminal, compact, corymb-like clusters. Four linear-oblong involucral bracts 4 to 8 mm long subtend each head. The densely white-hirsute to tomentose achenes are 4 to 6 mm

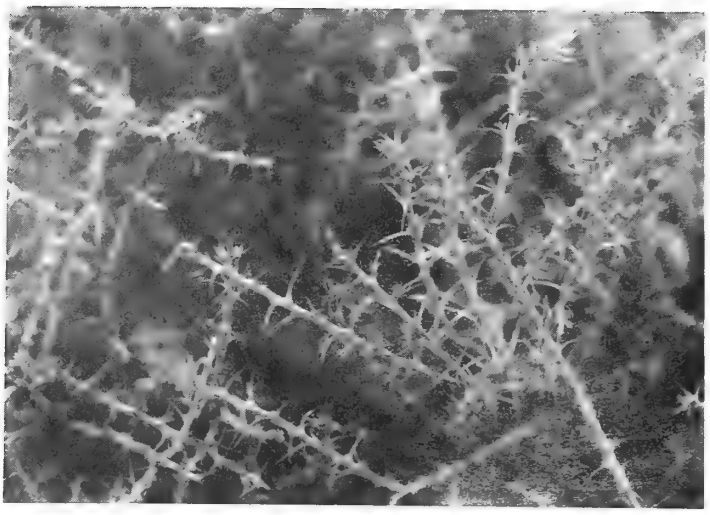

Figure 61.--Spines (arrow) on Nuttall horsebrush (T. nuttallii). Specigrowing in Antelope Valley, Sanpete Co., Utah.

long. Blooming occurs from late May to early July. Seeds are about 50 percent larger than those of *T. canescens*.

Hybridization.--Only diploid ($2n = 60$) populations have been reported for *T. nuttallii* (Strother 1974).

Distribution and habitat.--Nuttall horsebrush occurs in the badlands of southwestern Wyoming and in dry barren hills and plains of northeastern Nevada, northern half of Utah, and northwestern Colorado between 1,300 and 2,100 meters (4,300 and 6,900 feet) in elevation. It is usually associated with sagebrush and shadscale vegetational types.

Use.--The spiny growth habit precludes much use by animals except for cover. It contributes to the vegetal cover in dry, hostile environments.

Tetradymia spinosa Hook. & Arn. (spiny horsebrush[9])

Spiny horsebrush is a compact or spreading, much-branched spiny shrub to 12 dm high. Unlike the other horsebrushes mentioned in this paper, the dense, evenly pannose vestiture of the young stems is uninterrupted by streaks and is persistent as the stems age.

The primary leaves transform into stiff recurved spines 5 to 20 mm long. Fascicles of essentially glabrous, linear to narrowly spatulate, secondary leaves 3 to 15 mm long develop in the axils of the spines.

Flowering heads are produced singly or in pairs on short peduncles 1 to 1.5 cm long in the spine (primary leaf) axils formed the previous year. The heads usually contain 6 pale to bright yellow disc flowers. Five or 6 oblong to ovate, conspicuously tomentose, involucral bracts 8 to 12 mm long subtend each head. The achenes are covered with long white woolly hairs that more or less conceal the pappus of small, white, slender scales. Blooming normally occurs during May and June, but may extend into August.

Hybridization.--Only diploid ($2n = 60$) populations of *T. spinosa* have been reported (Strother 1974).

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[9]Other common names include cottonthorn horsebrush and catclaw horsebrush.

*Figure 62.--Flower head of snakeweed (*X. sarothrae*) illustrating ray flowers (arrow). Specimen growing at Wahsatch Station, Summit Co., Utah.*

Distribution and habitat.--This species is scattered throughout the Great Basin and adjacent areas from southwestern Montana across Idaho to southeastern Oregon and southward to northwestern New Mexico, Utah Nevada, and eastern California. In these areas, spiny horsebrush occurs at elevations of 850 to 2,400 meters (2,800 to 7,900 feet) in alkali sinks, and in shadscale, sagebrush, creosote, pinyon-juniper, and yellow pine vegetational types.

Use.--Like Nuttall horsebrush, spiny horsebrush is of little direct use to animals because of its growth habit. It does provide cover for smaller animals and is a useful soil stabilizer where it grows.

CHARACTERISTICS OF THE GENUS *XANTHOCEPHALUM*[10] (MATCHBRUSH, SNAKEWEED)[11]

This genus consists of perennial herbs and low suffrutescent shrubs (subshrubs) with woody roots, crowns, and stem bases. Its leaves are entire, linear to narrowly oblanceolate, and usually sticky from resin exuded to the surfaces of both leaves and young stems.

Numerous small heads form in loose or crowed terminal clusters. Resinous, imbricated involucral bracts with thin membranous margins and green tips subtend each head. A few yellow ray and disc flowers are both present (fig. 62). The ray flowers are usually pistillate and fertile while the disc flowers are usually perfect and fertile or sometimes staminate. Pappi of several small scales or awns are generally present, at least on the disc flowers. Achenes are small, oblong or obovoid, and pubescent. Blooming occurs from May to October.

The basic chromosome number for *Xanthocephalum* is x = 4 (Solbrig 1971; Pinkava and Keil 1977).

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[10]This genus has long been known as *Gutierrezia* (Ruffin 1974).

[11]Other common names include matchweed, perennial snakeweed, broom snakeweed, broomweed, resinweed, stinkweed, turpentine weed, and yellow top.

The numerous common names for this genus are perhaps indicative of its wide distribution. The genus consists of about 25 species scattered throughout western North and South America. Only two of these species, *X. sarothrae* and *X. microcephala*, are of importance in the Intermountain area. Other North American species include *X. bractereata*, *X. californica*, and *X. serothina*.

Matchweed commonly invades depleted ranges and is considered an indicator of overgrazed rangelands. Species in this genus are generally unpalatable and seldom grazed. When eaten in quantity, this plant is more or less poisonous to sheep and goats (Benson and Darrow 1944; Kearney and Peebles 1960).

Xanthocephalum microcephala Shinners (small headed matchweed[12])

Small-headed matchweed is a many-stemmed subshrub up to 6 dm tall. Its stems and leaves are glabrous and resinous. The leaves are linear-filiform and usually less than 1 mm wide.

Tiny heads, only 3 mm long and 1 to 1.5 mm wide, occur singly or are more often arranged in small terminal cyme-like clusters. The heads commonly have 1 to 3 disc flowers. Involucral bracts with yellow tips and prominent hyaline margins surround the heads.

Hybridization.--Some authors consider *X. microcephala* to be a subspecies or variety of *X. sarothrae* (Benson and Darrow 1944; Harrington 1954). This species forms a polyploid series with chromosome numbers of $2n = 16$, 24, and 32 (Solbrig 1971; Keil and Pinkava 1976).

Distribution and habitat.--This species occurs between 1,000 and 2,500 meters (3,300 and 8,200 feet) in elevation from Idaho southward to southeastern California, Arizona, New Mexico, Texas, and on into Mexico. It may be associated with the sagebrush, pinyon-juniper, yellow pine, and aspen vegetational types. Type locality is reported as "Saltillo, Mexico" (Abrams and Ferris 1960).

Use.- *Xanthocephalum microcephala* has poisoned large numbers of sheep and cattle under range conditions in Texas. It may cause death in acute cases, but abortion is more commonly the result of poisoning by this species. As long as the animals can find, or are provided with, sufficient supplementary forage, poisoning usually does not occur (Kingsbury 1964).

Xanthocephalum sarothrae Shinners (broom snakeweed)

Broom snakeweed is a subshrub up to 7 dm tall (fig. 58). It has a deep taproot, extensive lateral roots, and a woody crown from which grow numerous, slender, erect, brittle, essentially herbaceous branches. The branches and leaves are green, glabrous to puberulent, and slightly resinous. The leaves are also punctate, linear, 2 to 5 cm long, and 1 to 2 mm wide.

The heads contain from 3 to 8 ray and disc flowers each. Resinous, often green-tipped involucral bracts are arranged in a series of 2 to 4 rows around each head and many appear to be in somewhat vertical ranks. The bracts are 3 to 6 mm long and 2 to 3 mm wide. Blooming occurs from May to October. Broom snakeweed has 3,535 seeds per gram (1,605,000 seeds per pound).

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[12]Also known as thread-leaf matchweed.

Hybridization.--*Xanthocephalum sarothrae* has a basic chromosome number of $x = 4$. It is a polyploid species consisting most commonly of diploid ($2n = 8$) and occasionally of tetraploid ($2n = 16$) populations. Both the diploids and the tetraploids show considerable variation and grow intermixed through the range of species (Harrington 1954; Solbrig 1971; Pinkava and Keil 1977).

Distribution and habitat.--Broom snakeweed is the most abundant snakeweed in western North America. Many ecotypes have been found. It occurs in plains, valleys, foothills, and mountainsides from Saskatchewan and Alberta to southeastern Washington, southward to Texas and Baja California. It grows in a wide range of soil types at elevations between 900 and 3,000 meters (2,950 and 9,850 feet) and may be associated with such plants as creosote bush, mesquite (*Prosopis* spp.), soapweed (*Yucca* spp.), rabbitbrush, big sagebrush, black sagebrush, shadscale, pinyon-juniper, oak (*Quercus* spp.), Indian ricegrass (*Oryzopsis hymenoides*), grama grass (*Bouteloua* spp.), buffalo grass (*Buchloe dactyloides*), and cheatgrass (*Bromus tectorum*) (USDA Forest Service 1937).

The type locality of *X. sarothrae* is listed as the "plains of Missouri River" (Abrams and Ferris 1960).

Use.--This shrub is a very aggressive invader into areas where the climax vegetation has been depleted. It is considered an indicator of range deterioration because it is one of the first plants to invade when the range has been overgrazed and often becomes the principal plant cover. As such, it is important in protecting the soil against erosion. Broom snakeweed has usefulness as a pioneer shrub on other types of disturbed areas as well. It is not, however, competitive with other perennial cover.

Throughout its range, *X. sarothrae* is generally considered as poor forage and is grazed mainly because of lack of anything better. It is a secondary or facultative selenium absorber (Kingsbury 1964), and heavy use by livestock may cause sickness and death where it takes up this chemical. On many areas it is substantially browsed by livestock and game without any obvious ill effects. On the winter ranges of western Utah and eastern Nevada, this shrub is rated as fair forage of sheep which browse it most heavily after growth begins in the spring (USDA Forest Service 1937).

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APPENDIX

Compositae — Key to genera and species

1a. Head with both ray and disc flowers; pappus of several to many scales ..... *Xanthocephalum* 63
(matchbrush, snakeweed)

2a. Leaves linear-filiform, less than 1 mm wide; heads tiny, cylindrical, 1 to 1.5 mm thick; ray flowers 4 to 5; disc flowers 1 to 3..... *X. microcephala* 64
(small-headed matchweed)

2b. Leaves linear, 1 to 2 mm wide; heads larger, flaring; ray flowers 3 to 9, disc flowers 3 to 8..... *X. sarothrae* 64
(broom snakeweed)

1b. Heads with only disc flowers or if ray flowers present then pappus of capillary bristles or lacking.

3a. Pappus of capillary bristles, at least in part.

4a. Involucral bracts in a single series..... *Tetradymia* 58
(horsebrush)

5a. Stem vestiture evenly pannose; primary leaves forming rigid spreading or recurved spines; flowers 5 to 9 per head; involucral bracts 5 to 6; heads solitary or paired in upper axils; achenes with abundant long hairs that obscure the pappus; pappus of small scales.... *T. spinosa* 62
(spiny horsebrush)

5b. Stem vestiture interrupted by linear streaks; spines, if present, not spreading; flowers 4 per head; involucral bracts usually 4; heads arranged in corymbose clusters at ends of branches; achenes glabrous or with hair shorter than the pappus; pappus of numerous bristles.

6a. Primary leaves forming rigid spines..*T. nuttallii* 61
(Nuttall horsebrush)

6b. Primary leaves not forming rigid spines, but may be spinulose-tipped.

7a. Primary leaves linear-subulate, 0.5 to 1 cm long, mucronate or spinulose-tipped; herbage often becoming glabrate..... *T. glabrata* 60
(little-leaf horsebrush)

7b. Primary leaves linear-lanceolate to spatulate, 1 to 3 cm long, not mucronate or spinulose-tipped; herbage permanently canescent or tomentose..... *T. canescens* 59
(gray horsebrush)

4b. Involucral bracts of 2 or more series..... *Chrysothamnus* 36
(rabbitbrush)

8a. Twigs glabrous or finely puberulent. *Page No.*

9a. Flowers white; leaves glabrous with copius resinous exudate, surface with small pits; alkaline areas from western Utah to eastern California... *C. albidus* (alkali rabbitbrush) 39

9b. Flowers pale to dark yellow; leaves not as above.

10a. Achenes glabrous, or glandular only at distal end.

11a. Involucral bracts 5 to 7 mm long, with thick greenish apical tips, not strongly alined into ranks..... *C. vaseyi* (Vasey rabbitbrush) 53

11b. Involucral bracts 10 to 13 mm high, lacking thick greenish apical tips, strongly alined into 5 vertical ranks..... *C. depressus* (dwarf rabbitbrush) 39

10b. Achenes densely pubescent.

12a. Involucral bracts with narrowly acuminate, greenish tips..... *C. greenei* (Greenes rabbitbrush) 41

12b. Involucral bracts acute to obtuse.

13a. Heads somewhat turbinate, 5 to 6 flowered, shrubs large, up to 2.4 m tall; leaves 4 to 8 mm wide; involucral bracts thick with conspicuous green spots near obtuse apex... *C. linifolius* (spreading rabbitbrush) 42

13b. Heads narrowly cylindric, 3 to 5 flowered; shrubs various; leaves often twisted, 1 to 6 mm wide ..... *C. viscidiflorus* complex (low rabbitbrush) 54

14a. Leaves and upper stems glabrous.

15a. Shrubs usually over 5 dm tall, leaves 1 to 5 mm wide, 2 to 5 cm long; usually with very pungent odor..... *C. viscidiflorus* ssp. *viscidiflorus* (stickyleaf low rabbitbrush) 57

15b. Shrubs less than 5 dm tall; leaves 1 mm wide, 1 to 3 cm long, filiform; odor various ..... *C. viscidiflorus* ssp. *stenophyllus* (narrowleaf low rabbitbrush) 57

14b. Leaves and upper stems pubescent. *Page No.*

16a. Leaves 2.5 to 6 mm wide, 1.5 to 4 cm long; involucral bracts without thickened greenish spot near tip; common in mountains and upper foothills ..... *C. viscidiflorus* ssp. *lanceolatus* 56
(mountain low rabbitbrush)

16b. Leaves up to 2 mm wide, 3 cm long; involucral bracts often with thickened greenish spot near tips; occurs on dry plains, valleys, and foothills ..... *C. viscidiflorus* ssp. *puberulus* 57
(hairy low rabbitbrush)

8b. Twigs with often densely compacted tomentum or at least tomentose.

17a. Bracts very attentuate; inflorescence mostly racemose..... *C. parryi* complex 51
(Parry rabbitbrush)

18a. Flowers 10 or more per head..... *C. parryi* ssp. *parryi* 53
(Parry rabbitbrush)

18b. Flowers 9 or less per head.

19a. Inflorescence of single or paired heads..... *C. parryi* ssp. *monocephalus* 53

19b. Inflorescence racemose of several to many heads.

20a. Leaves with short-stalked resin glands..... *C. parryi* ssp. *asper* 52

20b. Leaves lacking stalked resin glands.

21a. Upper leaves longer than inflorescence; flowers 8 to 10 mm long, pale yellow..... *C. parryi* ssp. *howardi* 52
(Howard rabbitbrush)

21b. Upper leaves shorter than inflorescence; flowers 9 to 12 mm long, clean yellow.

22a. Bracts with straight tips; heads 11 to 15 mm long ..... *C. parryi* ssp. *attenuatus* — *Page No.* 52

22b. Bracts with recurved tips; heads 14 to 19 mm long ..... *C. parryi* ssp. *nevadensis* (Nevada rabbitbrush) — 53

17b. Bracts acute to obtuse; inflorescence mostly cymose ..... *C. nauseosus* complex (rubber rabbitbrush) — 43

23a. Leaves usually grayish-white; involucral bracts puberulant or tomentose.

24a. Leaves 3 to 10 mm wide, 4 to 8 cm long; bracts mostly obtuse..... *C. nauseosus* ssp. *salicifolius* (mountain rubber rabbitbrush) — 47

24b. Leaves 3 mm or less wide, 2.5 to 4 cm long; bracts mostly acute..... *C. nauseosus* ssp. *albicaulis* (white rubber rabbitbrush) — 45

23b. Leaves usually greenish-yellow; involucral bracts glabrous.

25a. Leaves 1 to 3 mm wide, 4 to 6 cm long; mildly ill-scented..... *C. nauseosus* ssp. *graveolens* (green rubber rabbitbrush) — 47

25b. Leaves less than 1 mm wide 2.5 to 5 cm long; strongly disagreeable odor..... *C. nauseosus* ssp. *consimilis* (threadleaf rubber rabbitbrush) — 46

3b. Papus lacking..... *Artemisia* (sagebrush) 3

26a. Heads with both ray (marginal) flowers and disc flowers; plants subshrubs or shrubs.

27a. Plants subshrubs; leaves 2 or 3 times pinnately parted, silky-canescent; widely distributed through western North America, Siberia, northern Asia, and Europe..... *A. frigida* (fringed sagebrush) 13

27b. Plants shrubs; leaves not as above.

28a. Branches spinescent; leaves 3 to 5 palmately parted with segments 3-lobed, white tomentose, deciduous; occurs on dry, saline plains and hills from northwestern Montana west to eastern Oregon and south to California, Arizona, and New Mexico..... *A. spinescens* (bud sagebrush) 24

28b. Branches not spinescent; leaves not as above.

29a. Leaves filiform, entire or ternately divided into filiform segments, silvery-white canescent; heads with 2 to 3 ray flowers and 1 to 6 disc flowers; occurs mostly in sandy soil from Nevada east to western Nebraska and south to Texas, Arizona, and Chihuahua..... *A. filifolia* (sand sagebrush) 12

29b. Leaves narrowly cuneate, mostly finely tridentate, silvery-canescent; heads smaller with 0 to 2 ray flowers and 1 to 3 disc flowers; occurs in canyons, gravelly draws, and dry flats from western Texas to California..... *A. bigelovii* (Bigelow sagebrush) 9

26b. Heads with disc flowers only; plants shrubs.

30a. Plants up to 5 dm high.

31a. Plants dwarf, less than 2 dm high.

32a. Plants depressed, cushionlike shrubs; leaves 2 to 8 mm long, pinnately divided into 3 to 11 lobes; limited to calcarious desert soils, central and western Utah, central and eastern Nevada, and northern Arizona..... *A. pygmaea* (pigmy sagebrush) 19

32b. Plants with decumbent, frequently layering branches; leaves often 3 cm long, deeply cleft into 3 linear lobes; rocky knolls from 2,430 to 2,740 m in central and southeastern Wyoming to southern Oregon..... *A. tripartita* ssp. *rupicola* 35
(Wyoming threetip sagebrush)

31b. Plants low from 2 to 5 dm high (but may be less).

33a. Heads axillary and sessile, generally all surpassed by their subtending leaves; leaves deeply divided into 3 to 5 narrowly linear lobes; deciduous ..... *A rigida* 20
(stiff sagebrush)

33b. Heads usually in branched racemose panicles or if spikelike, then subtending leaves do not surpass heads; leaves 3- to 5-toothed or lobed, cuneate to fan-shaped, persistent.

34a. Leaves broadly cuneate, deeply 3-lobed involucre broadly companulate; flower heads 3 to 5 mm broad with 6 to 11 disc flowers; blooming begins in mid-June; seeds 2.5 mm long, ripening in August; adapted to heavy, highly impermeable, alkaline soils from 1,800 to 2,450 m from southwestern Montana to northwestern Colorado, Utah, Nevada, Idaho, and Oregon ..... *A longiloba* 16
(alkali sagebrush)

34b. Leaves cuneate to broadly cuneate or fan-shaped, 3- to 5-toothed or cleft; involucre narrowly campanulate; flower heads and seed smaller than above; blooming normally occuring later than July; seed ripen late September and October.

35a. Leaves cuneate, 3-toothed (upper leaves may be entire), viscid; heads arranged in narrow spikelike panicles; disc flowers 3 to 5 per head; corollas 1.8 to 3 mm long; involucral bracts glabrous or nearly so; plants usually dark green with persistent red-brown inflorescent stalks; occurs on dry, shallow, rocky soil between 1,500 and 2,400 m in most western States ..... *A. nova* 17
(black sagebrush)

35b. Leaves broadly cuneate or fan-shaped, 3- to 5-toothed or cleft (upper leaves may be entire), not viscid; heads arranged in narrow racemose panicles; disc flowers 5 to 11 per head; corollas 3 to 4 mm long; involucral bracts canescent; plant usually lighter in color than above; distribution similar to *A. nova* but offset to the northwest, usually found at somewhat higher elevations in more moist habitats than *A. nova*..... *A. arbuscula* (low sagebrush) 6

30b. Plants usually over 5 dm high (39b and 42b provide most exceptions to 5 dm height).

36a. Leaves silvery-canescent, linear to linear-oblanceolate, mostly entire (occasionally with a few irregular teeth), or leaves deeply divided into 3 or more linear or linear-oblanceolate lobes.

37a. Leaves entire or occasionally with 1 or 2 irregular teeth or lobes..... *A. cana* (silver sagebrush) 10

38a. Leaves 2 to 8 cm long, 1 to 10 mm wide, densely silky-canescent; heads arranges into dense leafy panicles; occurs mostly east of the Continental Divide from southern Canada to northern Colorado..... *A. cana* ssp. *cana* (silver sagebrush) 12

38b. Leaves smaller than above (up to 7 cm long, 1 to 5 mm wide) and often crowded into dark-green clusters; heads arranged into dense, short raceme or spikelike inflorescences; occurs mostly west of the Continential Divide from southwestern corner of Montana to Arizona and New Mexico ..... *A. cana* ssp. *viscidula* (mountain silver sagebrush) 12

37b. Leaves typically deeply divided into 3 linear or narrowly lanceolate lobes which in turn may be 3-cleft..... ..... *A. tripartita* (threetip sagebrush) 34

39a. Plants freely branching shrubs up to 2 m; leaves 1.5 to 4 cm long, deeply divided into 3 linear lobes, each less than 1 mm wide; occurs on dry, well-drained soils from 900 to 1,800 m from British Columbia south to northern Nevada, northern Utah, and western Montana..... *A. tripartita* ssp. *tripartita* 35
(tall threetip sagebrush)

39b. Plants dwarf shrubs with decumbent, often layering branches; leaves up to 3 cm long, deeply divided into linear lobes 1 mm or more wide; occurs on rocky knolls from 2,430 to 2,740 m in central and southeastern Wyoming to southern Oregon ..... *A. tripartita* ssp. *rupicola* 35
(Wyoming threetip sagebrush)

36b. Leaves not silvery-canescent, narrowly lanceolate to broadly cuneate or fan-shaped, typically 3-toothed or lobed (upper leaves may be entire).

40a. Plants low-growing, flat-topped shrubs up to 8 dm high; leaves somewhat viscid; heads occurring singly or occasionally up to 3 arranged in short interrupted spike or racemelike inflorescences; heads large with up to 20 disc flowers each; occurs in high mountainous areas of central Colorado, western Wyoming, Utah, central Sierras of California, and Carson Range of Nevada..... *A. rothrockii* 23
(timberline sagebrush)

40b. Plants ranging from dwarf to tall, arborescent forms up to 4.5 m; leaves not viscid; inflorescences of numerous heads arranged into leafy panicles; heads smaller with 3 to 8 disc flowers; most widespread and common shrub of western North America..... *A. tridentata* 26
(big sagebrush)

41a. Plants uneven-topped shrubs with flowering stalks arising throughout the crown; leaves narrowly lanceolate to cuneate; odor of crushed leaves pungent.

42a. Mature plants often arborescent (with single trunklike main stem), usually from 1 to 2 m but in some forms up to 4.5 high; leaves narrowly lanceolate with margins not curving outward; average persistent 5.6 times its width; blooming starts in late August or September; odor strongly pungent; normally occurs below 2,100 m in dry deep, well-drained soils on plains, valleys, and foothills ..... *A. tridentata* ssp. *tridentata* 30
(basin big sagebrush)

42b. Mature plants with several main branches usually less than 1 m high; leaves narrowly cuneate to cuneate with margins curved outward; average persistent leaf length is 3.1 times its width; blooming starts in late July or August, odor pungent; occurs on dry, shallow, gravelly soil from 1,500 to 2,100 m ..... *A. tridentata* ssp. *wyomingensis* 33
(Wyoming big sagebrush)

41b. Plants usually even-topped shrubs with flower stalks arising from upper crown portions; leaves broadly cuneate to spatulate; average persistent leaf length is 4.0 times its width; blooming may begin in July; odor slightly pungent to pleasantly mintlike; occurs from 1,400 to 3,000 m in deep well-drained soils..... *A. tridentata* ssp. *vaseyana* 31
(mountain big sagebrush)

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1979. Characteristics and hybridization of important Intermountain shrubs. III. Sunflower family. USDA For. Serv. Res. Pap. INT-220, 82 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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